SEPTEMBER, 1948

WELDING Journal

The Journal of the American Welding Society

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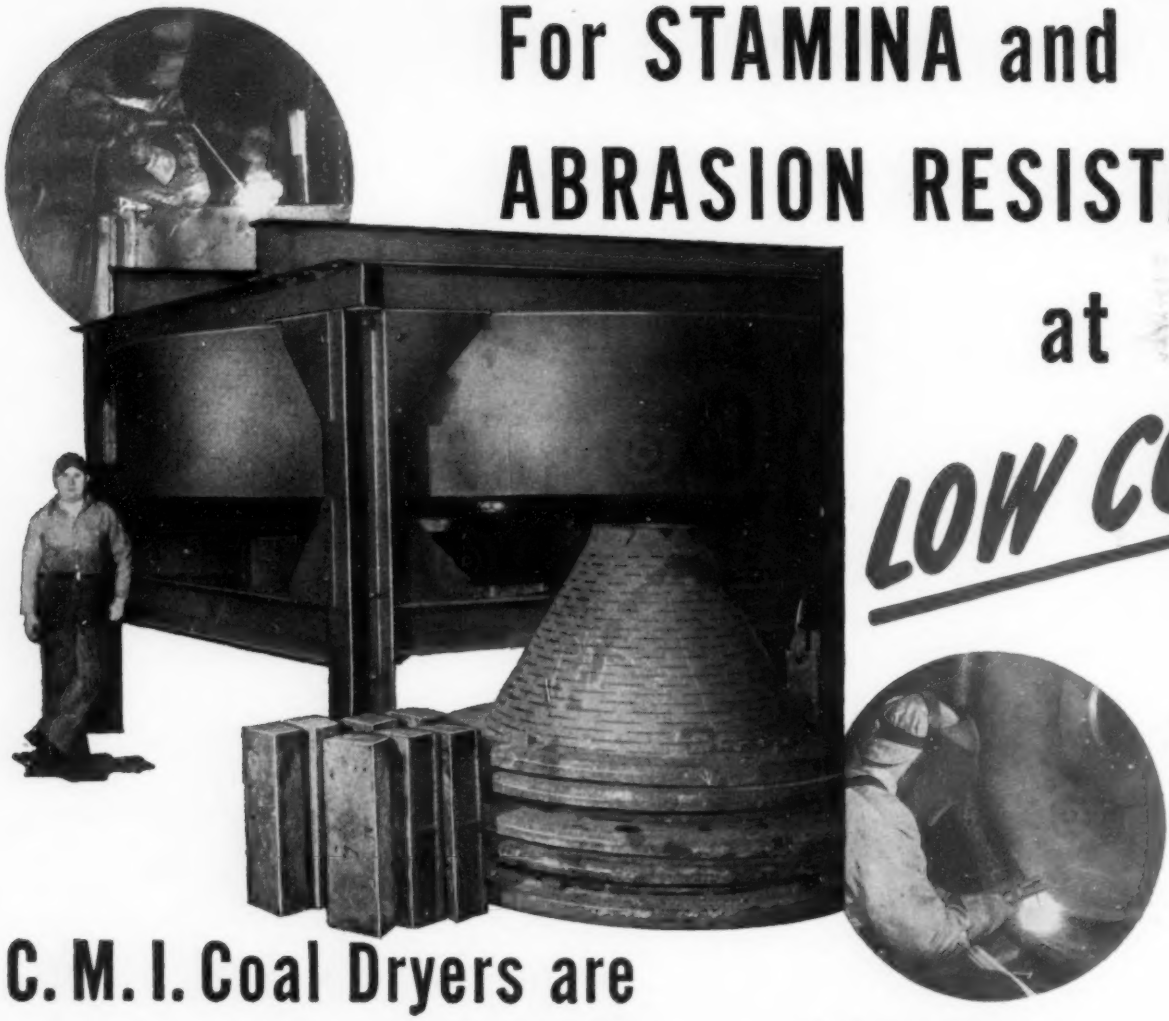

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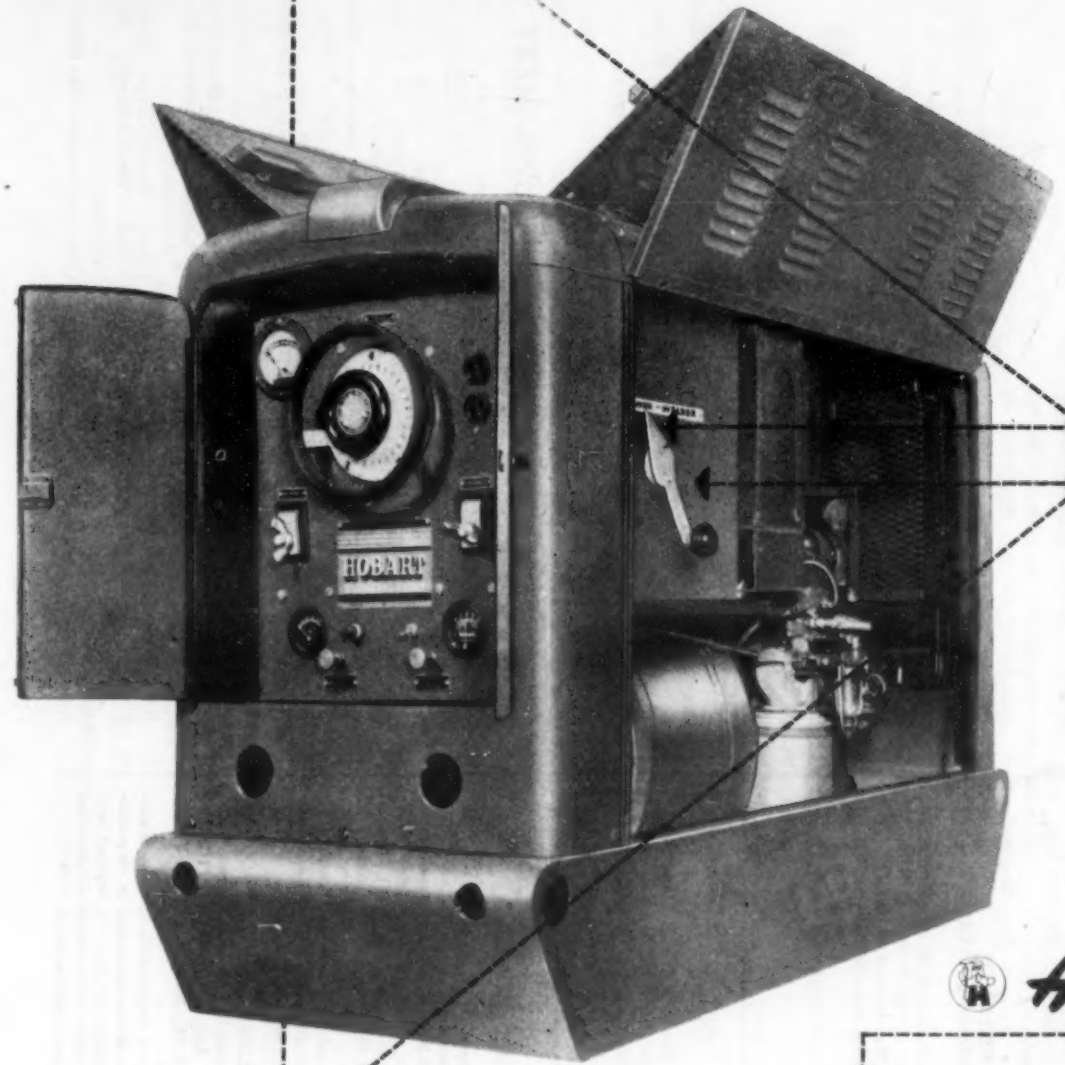

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The Journal of the American Welding Society

Published for the Advancement of the Science and Art of Welding

W. SPRARAGEN, Editor

SEPTEMBER 1948

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COVER

Welded Steel 400-Ton Capacity Floating Drydock Built for the Erie Railroad by Dravo Corporation, Pittsburgh.

ISSUED MONTHLY

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New Factors to Be Considered in the Design and Welding of Ships*

By Milton Forman†

THE past fifteen years has seen an unprecedented expansion in the application of welding. Not only has welding replaced riveting and casting in many fields, but a multitude of new products have been developed through the use of this highly versatile process.

The greatest progress has been achieved in the design and fabrication of small and medium sized structures. Here, welding has been tried and tested, and is accepted as the best and most economical process. Its application has especially been wide in the following industries: pressure vessels, machinery, sheet metal, ordnance, automotive, railroad, etc.

However, certain difficulties have been encountered in the design and construction of large all-welded structures such as bridges and ships. The highly publicized failures of T-2 Tankers and Liberty ships are still haunting the welding industry. The failures of these ships and some bridges acted as a catalyst for large scale research and scientific investigation into the characteristics of steel, the effect of welding and the standards of design for welding. These investigations have borne fruit and we are closer to a fuller understanding of the problem and its solution.

Riveted Ships Have Also Failed

It should be mentioned that structural failures were not limited to welded ships. E. M. MacCutcheon has reported that the *Oakley L. Alexander*, the *Oklahoma* and the *Mielero*, all riveted ships, broke in two in a manner practically identical to the failures of the welded ships. In addition, it is known that the *Leviathan* and the *Majestic* cracked their main decks. There is no doubt that there were many less spectacular fractures on riveted ships which have never been recorded. It has only been since the failure of welded ships built in World War II that complete records have been kept.

Approach of Designer

In the past, a naval architect, in designing a ship, was limited by a rather static point of view. He estimated the load and computed the stress assuming that each component part would carry its proportion of the load. This was assumed regardless of the notch or discontinuity inherent in the design. That is why hatch corners were designed square, and felt to be safe if the scantlings were sufficient. It has long been known, and sad experience has again taught us that sharp discontinuities concentrate stress in a relatively small area, and that this concentration of stress can exceed the fracture strength of the material in way of the notch. Thus, the structure can fail at a load far below its design strength. This is especially true if local elongation does not occur near the notch and thereby prevent a redistribution of stresses to other locations away from the root of the notch. This basic fact holds true whether the structure is riveted or welded. The reason why riveted structures do not seem to be as susceptible to notch effects is that a certain amount of elongation and slippage takes place at the riveted joints and the stress concentration is reduced at the notch itself. The general behavior is the same, the degree of stress concentration and the elongation of the specimen as a whole is different.

Difference Between Riveted and Welded Structures

As we all know, the very act of welding develops a continuity which had not previously existed in riveting. This continuity results in a different set of conditions for the transmission of stresses when a load is applied to the structure. Figure 1 portrays a simplified version of what

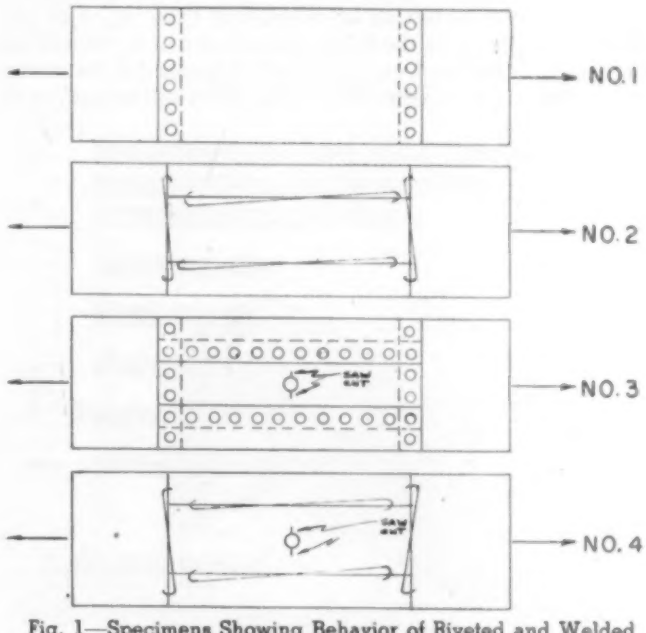

Fig. 1—Specimens Showing Behavior of Riveted and Welded Structures When Loaded

* Scheduled for Twenty-Ninth Annual Meeting, A.W.S., Philadelphia, Pa., week of Oct. 24, 1948.
† Formerly, Welding Engineer, United Engr. Co. now Welding Engineer, Battelle Memorial Institute.

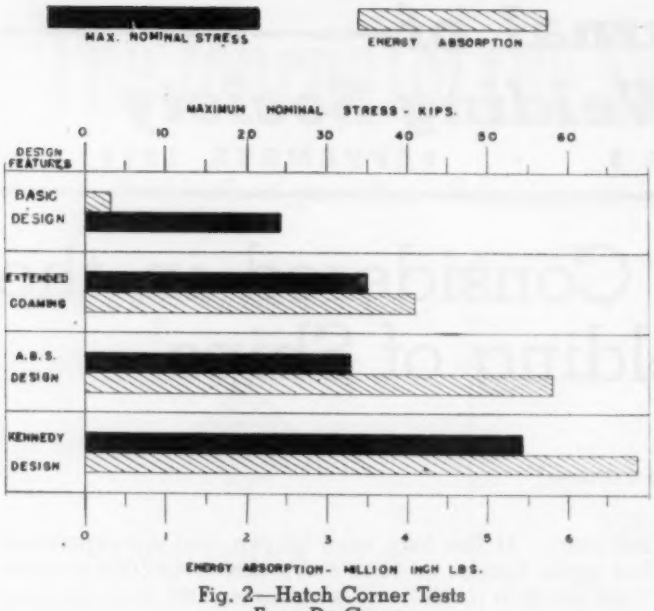

Fig. 2—Hatch Corner Tests
From De Garmo

happens. When the unnotched riveted specimen No. 1 is pulled in tension, there will be a concentration of stress at the many rivets, and as the load is increased, slippage will occur at the rivets. If the rivet size and spacing are correct, the specimen will fail only after its full design strength has been utilized. The specimen will behave in a ductile manner and the fracture will be shear in character.

In the case of unnotched welded specimen No. 2, the full design strength will also be achieved. However, there will be nothing to impede the uniform distribution of stress throughout the entire section. The specimen will also act in a ductile manner and a similar shear fracture will result. It is therefore evident that unnotched specimens, both welded and riveted, will develop their full design strength. Of course, the riveted specimen would either have to be wider or thicker in order to sustain a load equal to that of the welded one.

However, when the notched specimens Nos. 3 and 4 are tested, it will almost be impossible to predict their point of failure by calculating the effective cross-sectional area. The riveted specimen No. 3 will undoubtedly absorb more energy before failure. For, when the load is applied, a redistribution of stress will take place at the rivets, and therefore the full concentration of stress will not immediately be developed at the notch located in the center of the plate. In specimen No. 4, the stress will be uniformly distributed except in the area of the notch. There will be a greater concentration of stress at the notch with no dissipation at the rivet holes. In addition, *the notch in the welded specimen may be more effective because of greater constraint or "size" effect.* The mass of restraining material in the area of the notch is greater in the continuous, welded specimen than in the discontinuous riveted one. On the whole, the riveted specimen will act in a more ductile manner.

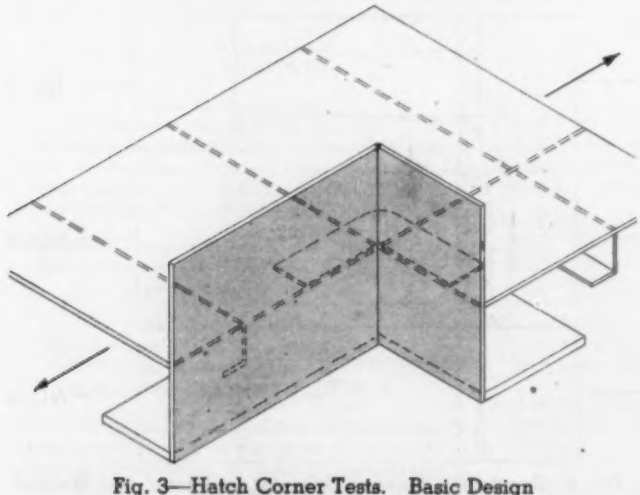

Fig. 3—Hatch Corner Tests. Basic Design
From De Garmo

Importance of Design

The research of the past few years has tended to concentrate attention on notch sensitivity as the basic cause of ship fractures. While it is true that the low notch toughness of ship steel is a precondition for premature failure, I believe more emphasis can be placed on the design aspects of the problem. Recent work done at the University of California and statistical records of the U.S. Coast Guard seems to bear this out.

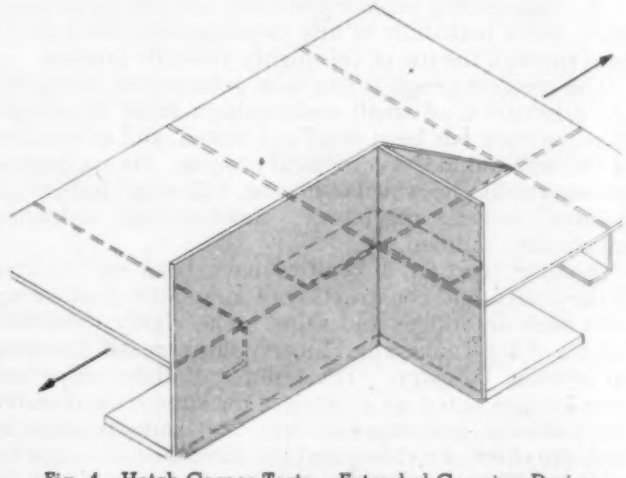

Fig. 4—Hatch Corner Tests. Extended Coaming Design
From De Garmo

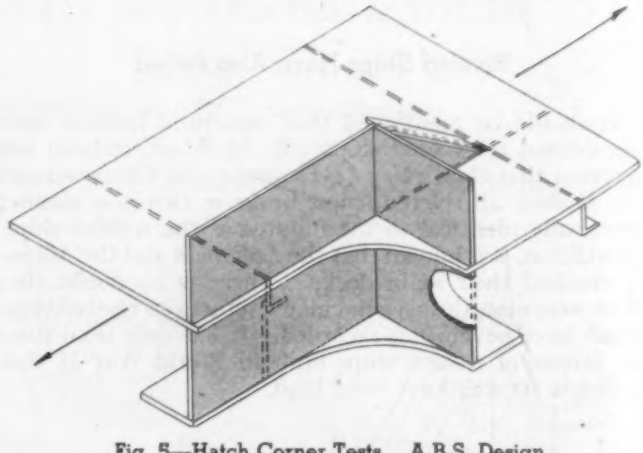

Fig. 5—Hatch Corner Tests. A.B.S. Design
From De Garmo

Effect of Design on Hatch Corners

Figure 2 charts some of the results of hatch corner tests at the University of California. It is to be noted that in each case the same notch sensitive ship steel was used, and the welding electrode and welding procedure was standard. *A careful analysis of the results shows that any design change which tended to alter the flow of stress from the square hatch corner itself, brought greatly improved re-*

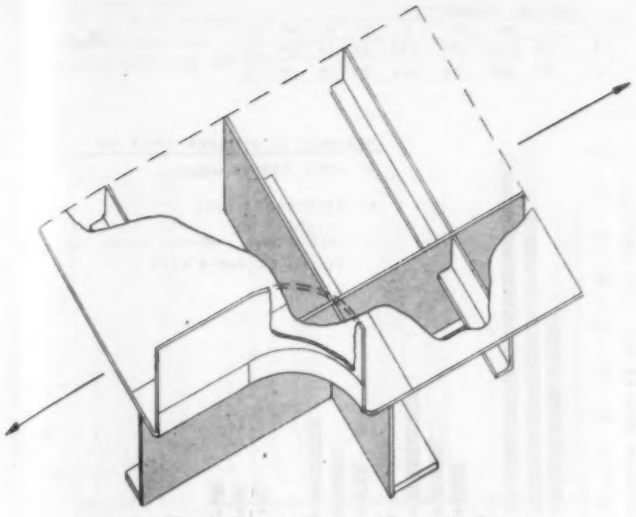

Fig. 6—Hatch Corner Tests. Kennedy Design
From De Garmo

sults. The basic square hatch corner is shown in Fig. 3. The only improvement in Fig. 4 is that the longitudinal coaming was extended for one frame space to attach to the deck. This allowed a fair proportion of the load to be carried to the deck itself instead of concentrating it at the corner.

The A.B.S. design in Fig. 5 is a combined rounded and square design. It is to be seen that it also shows decided improvement over the basic design. However, the maximum nominal stress as shown in Figure 2 is slightly below the extended coaming design, while the energy absorption is considerably improved. In essence, both Figs. 4 and 5 remain square hatch corners with alterations to avoid the full concentration of stress at the square discontinuity. The extended coaming seems most effective in increasing the breaking stress while the rounded off deck and girder flange of Fig. 5 seems to contribute most to increasing ductility and energy absorption.

Kennedy Design Is Best

Figure 6 shows the ideal Kennedy design. Here, for the first time, all aspects of a square hatch corner have been eliminated. A smooth transition has been achieved from every point of view. The test results in Fig. 2 show that the maximum nominal stress and the energy absorption is now within close range of the standard

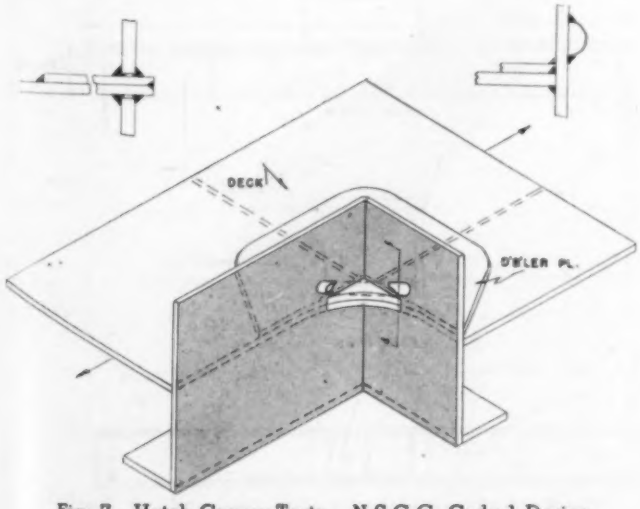

Fig. 7—Hatch Corner Tests. N.S.C.G. Code 1 Design
From De Garmo

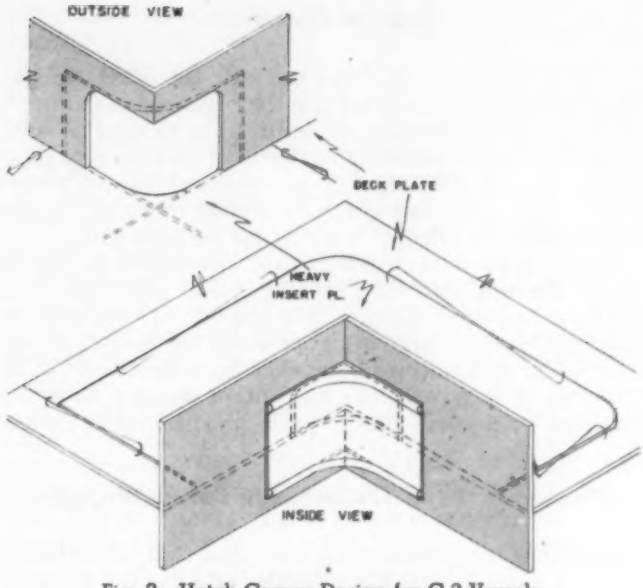

Fig. 8—Hatch Corner Design for C-3 Vessels
Developed at Ingalls Ship Corp.

0.505-in. tensile specimen. Therefore, despite the inherent design discontinuity, almost ideal conditions have been achieved for a smooth transmission of stresses.

Test Correlation with Actual Service

E. M. MacCutcheon has reported that the University of California test results conform well with the actual service of these hatch corners on ships. (It is to be noted that the Kennedy design has not as yet been used in ship construction.) Mr. MacCutcheon's discussion also points out that the hatch corner shown in Fig. 7 has had 7722 ship months' service time and no fractures have ever been reported. The test results at the University of California of this hatch corner showed that the maximum nominal stress and energy absorption was about equal to the results shown in Fig. 2 for the extended coaming design. Since the correlation with actual service is favorable, it should be possible, within limits, to predict the ship service of various types of hatch corners on the basis of the full-scale tests. As such, there should therefore be good reason to accept the Kennedy design as ideal for ship design.

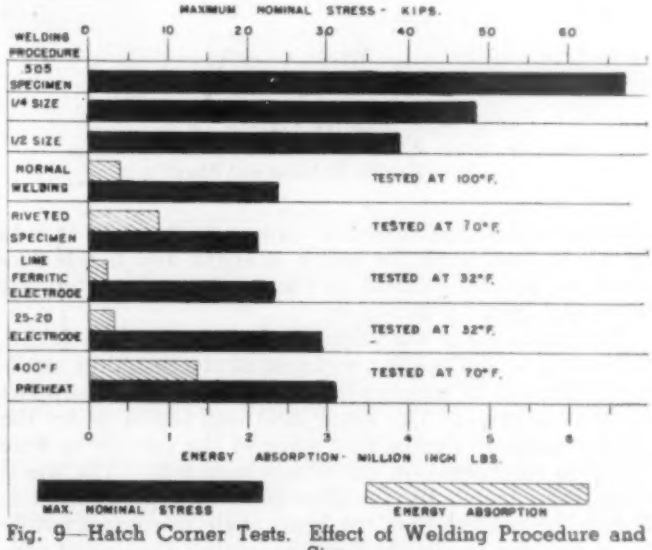

Fig. 9—Hatch Corner Tests. Effect of Welding Procedure and Size
From De Garmo, Merrian and Grassi

General Comments

It is to be noted that contrary to the other designs, the Kennedy type does not use the principle of reinforcement as a strengthening measure. The design, as such, allows for ductile behavior under load and permits practically the full utilization of the physical test properties of the steel. The low notch toughness plays practically no role since the effect of a notch has been avoided.

Figure 8 shows a hatch corner, developed at Ingalls during the war, and used on C-3 Hulls. Although I do not have complete service time records, it was used on many ships which have been operating for years. To my knowledge, no fractures have ever been developed at it. Although it is superior to most other designs, it is my opinion that it is still inferior to the ideal Kennedy design.

Effect of Size and Thickness on Design Strength

Available test information indicates that plate thickness and specimen size has a decided effect of the strength of structures where an inherent notch exists. The results of some further tests at the University of California makes available interesting information on this subject. Part of the test results of Fig. 9 are rather illuminating. The full-size basic square design specimen, normally welded, broke at a maximum nominal stress of 24,000 psi. The half size specimen reached a maximum stress of 39,000 psi., while the quarter size specimen reached as high as 48,000 psi. The effect of specimen size, therefore, had a major effect, since this was the only variable in these tests. Some other interesting test results are shown in Fig. 10 on notched tensile specimens of various diameters. It is to be noted that both the notch strength and notch ductility are greatly reduced as the specimen diameters are increased from $^1/_4$ to $1^1/_2$ in.

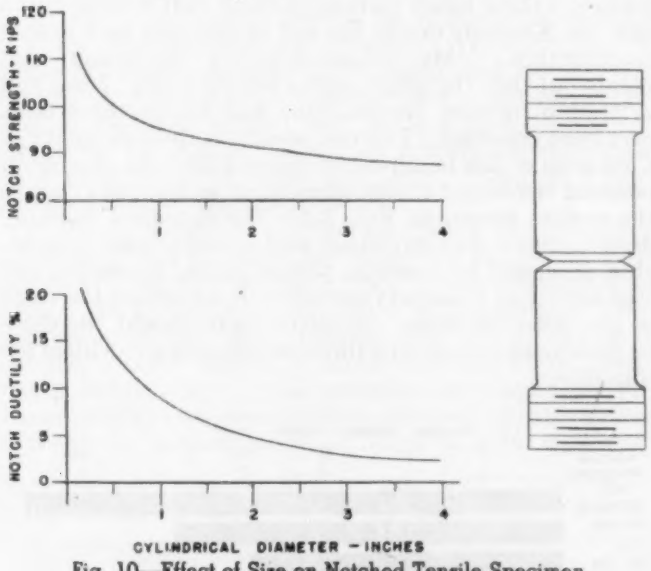

Fig. 10—Effect of Size on Notched Tensile Specimen
From Brown, Lubahn and Ebert

The thickness of the plate seems to have a distinct relationship to the notch toughness of the resultant structure. Figure 11 supplies additional evidence in support of this assertion. The same steel was tested under the same conditions except that some of the specimens were $^1/_2$ in. in thickness and the others were 1 in. The specimens were tested by the slow-bend notched-bead test. It is to be noticed that the bend angle is approximately $^1/_3$ in the case of the thicker 1-in. plate. One could conclude from this that the effectiveness of the notch is dependent on the mass of restraining material in the immediate area.

CHEMICAL COMPOSITION

STEEL	C	MN	P	S	SI	NI	CR	CU
2F	.30	0.76	.035	.040	.20	.13	.04	.22
4F	.37	1.50	.016	.032	.23	.10	.05	.22

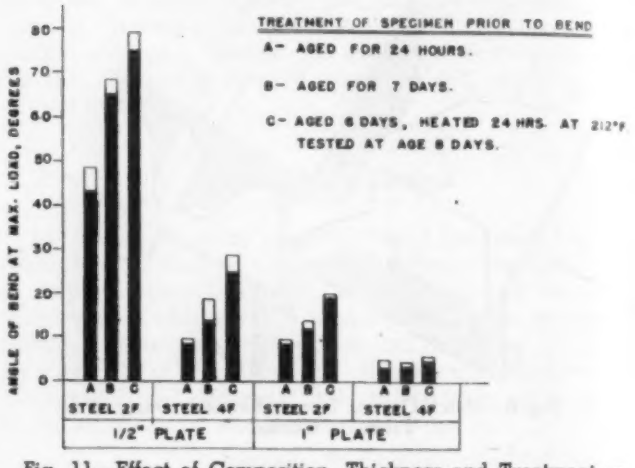

Fig. 11—Effect of Composition, Thickness and Treatment on Welded Specimen
From Voldrich, Bennett and Martin

The above results may indicate a new approach to designing in way of discontinuities. *It may be advisable to make every effort to reduce the thickness of plating in way of discontinuities, instead of increasing the same through the use of doubler plates.* The above may possibly be achieved, either throu gh the use of higher strength steels in way of discontinuities, or by designing the structure so that the heavier members are located in those portions which contain no change in continuity.

Box Girder Tests at National Bureau of Standards

Five large 9 ton girders were built for testing at the National Bureau of Standards. Each was 23 ft. 6 in. long and constructed from $1^1/_2$- and $2^1/_2$-in. plate as shown in Fig. 12. The girders were designed and welded in order to develop the most severe restraint through an abusive welding sequence and excessive welding. The aims of the tests were to determine the effect of testing temperature and severe geometrical constraint on a large rigid structure. Care was taken that the design and workmanship did not introduce a deliberate notch effect.

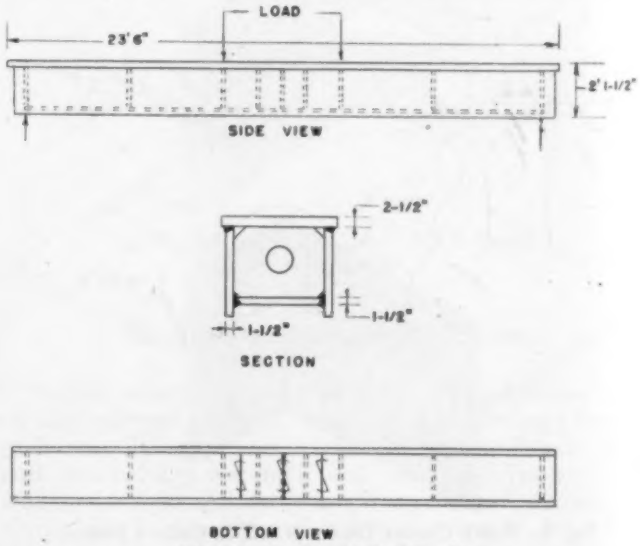

Fig. 12—Design of Box Girder

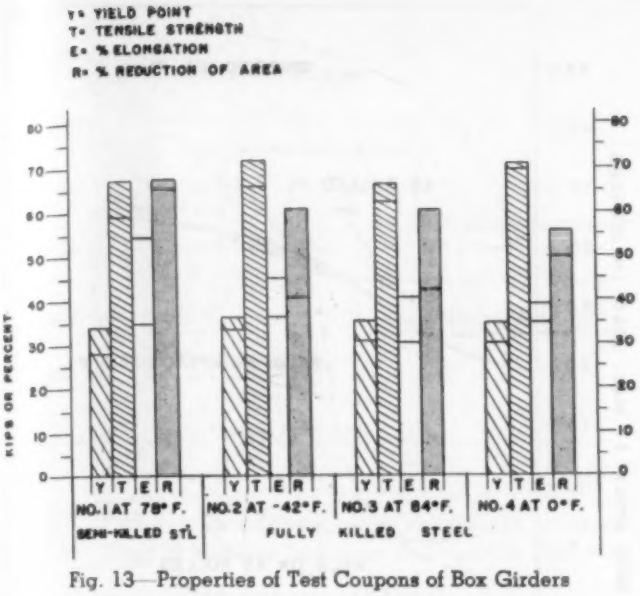

Fig. 13—Properties of Test Coupons of Box Girders

The welding sequence was executed to develop as high reaction and residual stresses as possible.

An examination of the physical properties as measured by tensile specimens are recorded in Fig. 13. A glance will show that the semikilled, ship steel of Box Girder No. 1 did not vary much from the fully killed steel of the other girders. In fact, the semikilled steel had better elongation and reduction in area than the fully killed steel. Also, various testing temperatures of the fully killed steel, as measured by an unnotched tensile specimen, showed very little difference in test results in terms of yield point, ultimate tensile strength, elongation and reduction in area. However, the impact values resulting from the Charpy test with an Izod notch, showed very great discrepancies between the two steels, as well as much lower values with a decrease in temperature. The semikilled steel had much lower impact values at room temperature (Fig. 14).

Test Results

There seems to be a rough correlation between the impact values and the test results. When the impact values were below 25 ft.-lb. at a specific testing temperature, the girders broke in a brittle manner. When the impact values were above 25 ft.-lb., the girders behaved in a completely ductile manner and did not break at all. As shown in Fig. 15, fully killed Box Girder No. 4 tested at 0° F. resisted a greater load than semikilled Girder No. 1 at 78° F.

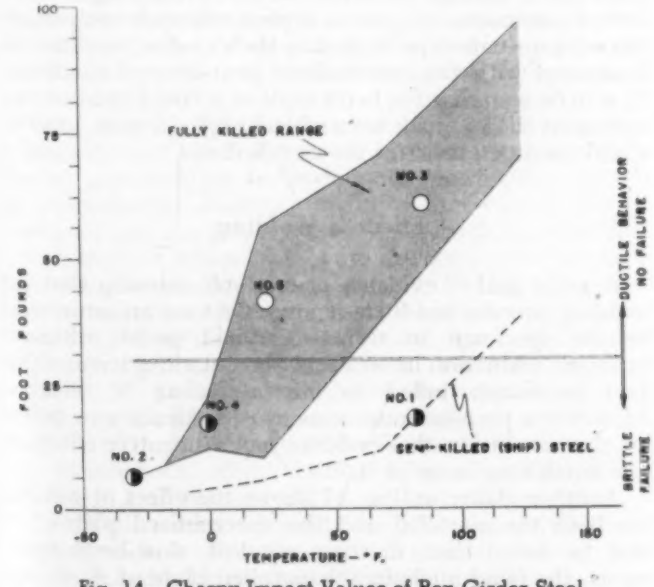

Fig. 14—Charpy Impact Values of Box Girder Steel From Boyd

It is important to recognize that despite the low impact values of the steel itself, 4 of the 5 girders, developed more than their calculated design strength at the extreme fibers of the side plate. Even in the case of Box Girder No. 2, tested at −42° F., the calculated stress at the extreme fiber was 60,000 psi. as compared to the ultimate tensile strength of the test coupon of 70,000 psi., at the same temperature.

It would therefore seem that a *welded structure without a design notch can develop more strength than indicated by the tensile test coupon*. This is even more important, since previous emphasis in the case of welded structures has been that they never seem to perform as well as unwelded structures when a notch effect exists. The low notch toughness of steel tended to becloud the fact that well designed unnotched structures perform in a ductile manner and easily fulfill their design strength under normal operating conditions.

Greater Familiarity with Steel Needed

In the past, some naval architects seemed to be concerned but little with all of the properties of steel or its testing. We all know that the accepted physical tests of steel to determine whether it meets specifications only

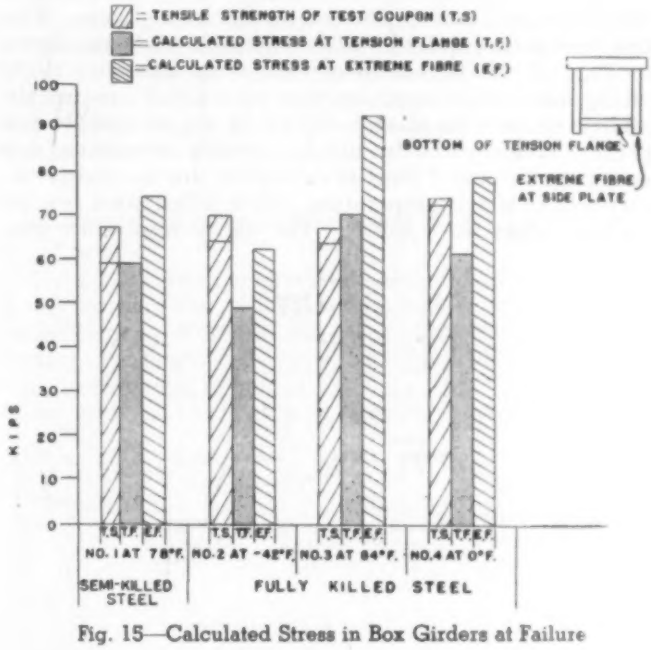
= TENSILE STRENGTH OF TEST COUPON (T.S)
= CALCULATED STRESS AT TENSION FLANGE (T.F.)
= CALCULATED STRESS AT EXTREME FIBRE (E.F.)
BOTTOM OF TENSION FLANGE
EXTREME FIBRE AT SIDE PLATE
KIPS
NO. 1 AT 78°F.
NO. 2 AT -42°F.
NO. 3 AT 84°F.
NO. 4 AT 0°F.
SEMI-KILLED STEEL
FULLY KILLED STEEL

Fig. 15—Calculated Stress in Box Girders at Failure

use ideal, unnotched conditions. Since we were not too well aware of the importance of notch sensitivity, little effort was put into eliminating those design features which produced a notch effect. The research and thinking of the past few years has placed great emphasis on this very important characteristic of steel. Notch toughness is not at all a static property of steel. It varies much more than any of the other properties of steel when influenced by any single one of the following factors; sharpness of the notch, rate of loading, temperature, deoxidation practice in the making of the steel, metallurgical structure.

Sharpness of Notch

It is rather obvious that the sharper the discontinuity or notch effect, the greater will be the concentration of stress at the root of the notch. In addition, the sharper the notch, the more it will tend to restrict plastic, ductile behavior and cause the structure to fail at a lower load and in a brittle manner. Laboratory evidence substantiating the above has been presented by Zeno and Low. Their tests show that the sharper the notch, the higher is the transition temperature to brittle fracture. Also, the deeper the notch for a given specimen thickness, the lower is the transition temperature. The latter again emphasizes the "size" effect, since the deeper the notch, the less is the mass of restraining material and the less is the constraint.

Rate of Loading

It has been fairly well established that the more rapid the loading rate on a notched specimen, the lower will be its resistance to fracture. The rate of loading, however, becomes a factor when its value is well above those produced by static loading. In the case of ships, the loading rates are rather low and fall within the general range of static loading. From all information available to this author, in no case has it been established that the loading rates encountered in ship operation reach a point where they would be considered a significant factor.

Temperature

The lower the temperature, the less is steel able to absorb energy, and the lower is its notch toughness. This has been rather well established by such studies as shown in Fig. 16. It is readily evident from this that slight changes in temperature, such as 10 or 15° F., reduce the ability of steel to absorb energy to an alarmingly low point. When tested by notched tensile specimens, it is noted that rimmed steel is extremely low in energy absorption at room temperature, while killed steel reaches its low values at +10° F. The above results are confirmed by many tests including the standard impact and slow bend tests.

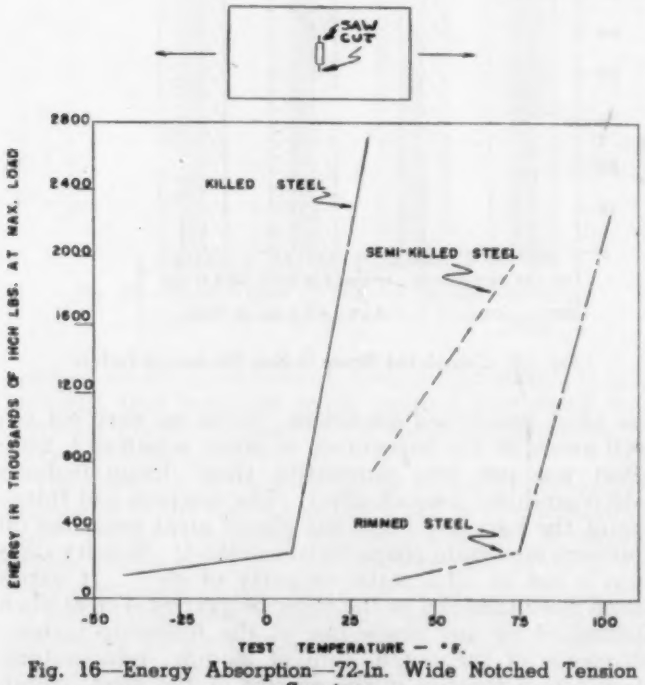

Fig. 16—Energy Absorption—72-In. Wide Notched Tension Specimen
From H. Hiemke

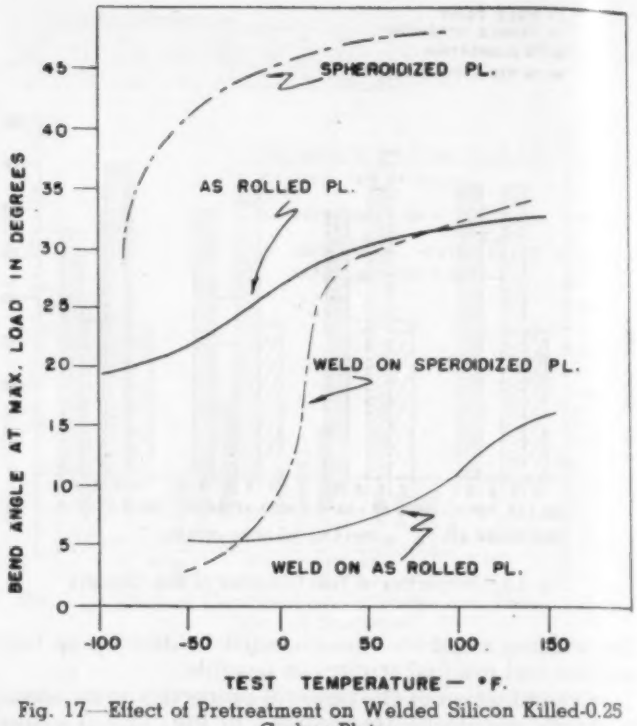

Fig. 17—Effect of Pretreatment on Welded Silicon Killed-0.25 Carbon Plate
From Stout and McGeady

Deoxidation Practice

Deoxidation practice in the steel mill has long been known to have a decisive effect on the impact values and notch toughness of steel. Another glance at Fig. 16 confirms this when the semikilled and fully killed steels are compared. At 25° F., killed steel absorbed almost 2,800,000 in.-lb., while the semikilled steel absorbed less than 800,000 in.-lb.

Heat Treatment and Metallurgical Structure

The heat treatment and metallurgical structure of steel has a decided influence on the notch toughness of tested specimens. Figure 17 depicts one such comparison between a single type of steel in the as-rolled condition as compared with the spheroidized heat-treated condition. It is to be seen that the bend angle of a slow-bend notched specimen shows much better bend angles for the spheroidized specimen than for the as-rolled one.

Effect of Welding

A great deal of evidence is available showing that the welding process has little if any effect on an unnotched tensile specimen in terms of yield point, ultimate strength, reduction in area and percent elongation. This fact previously lulled us into a feeling of security. However a preponderant amount of evidence now points to the conclusion that welding has a negative effect on the notch toughness of steel.

Another glance at Fig. 17 shows the effect of welding on both the as-rolled and the spheroidized plates. It will be noted that, in these notched, slow-bend specimens, the bend angle in the as-rolled plate at 0° F. was reduced from 27 to $5^1/_2$°. The spheroidized plate suf-

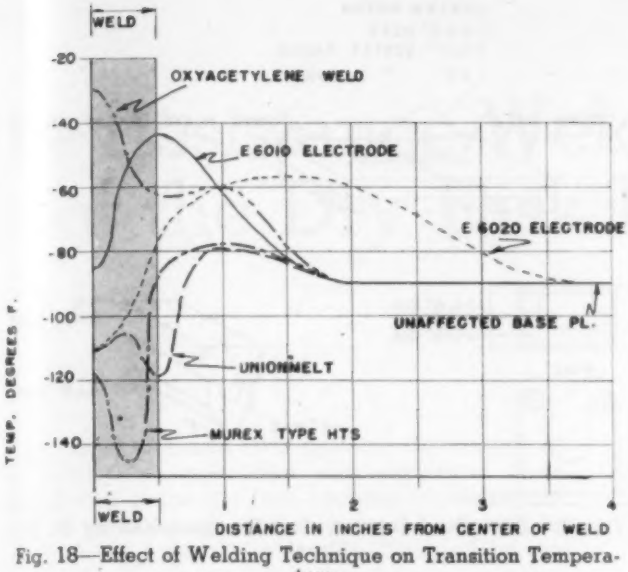

Fig. 18—Effect of Welding Technique on Transition Temperature
From Grossman and Shepler

fered similar results with the bend angle being reduced from 45 to 10° at the same temperature.

This detrimental effect of welding on notched specimens has also been confirmed by all other tests which attempt to evaluate notch toughness and notch ductility. It must be emphasized that a sharp notch or discontinuity must be present in order for this effect of welding to become operative. It should also be considered that structures, which are well designed and constructed through the elimination of any type of notch effect, perform extremely well.

Welding Procedures Can Improve Performance

The performance and strength of a welded structure can be improved by the use of different types of electrodes, preheating, postheating and special welding procedures.

Welding Electrodes: Referring back to Fig. 9, it will be seen that the use of 25-20 stainless steel electrodes and the lime coated ferritic electrodes tend to give better performance when used on the full-sized, square hatch corners. The two hatch corners, welded with the above two electrodes, were tested at a temperature of 68° F. below the normally welded one. Yet, the lime-coated, ferritic-welded one shows about the same strength, and the 25-20 stainless steel welded one shows an increase of approximately 5000 psi.

The above is confirmed by an analysis of the transition temperatures to brittle fracture of various types of electrodes and welding methods portrayed in Fig. 18. It is immediately evident that the lime-coated ferritic electrode and the process of automatic welding gave very low transition temperatures in the weld metal as compared to the unaffected base plate. The highest transition temperature is encountered about 1 in. from the center of the weld in the heat-affected zone. At that, the highest transition temperature at this point is never more than 13° F. above that of the unaffected plate.

The use of E-6020 electrodes shows better results than E-6010. The E-6010 electrode shows its worst effect at the fusion zone, while the E-6020 reaches the highest transition temperature well in the heat-affected zone.

It is rather interesting to note that the oxyacetylene welding process offers the poorest results, and the zone most affected is the center of the weld itself.

It is to be remembered that, in the testing of notched specimens, the lower the transition temperature to brittle fracture, the better is the notch toughness of the steel.

Many reasons have been advanced for the diverse effect of different types of electrodes and processes on the notch toughness of steel. Some of these reasons include: heat input and its effect on the metallurgical structure due to a change in the cooling rate, chemical composition and hydrogen content of the weld metal and, to a much smaller extent, stresses due to the welding process itself.

Heat Input Affects Notch Toughness

Heat input, as measured by welding speed where other factors are constant, seems to have a direct effect on notch toughness. Figure 19 amply shows that a welding speed of 6 in. per minute results in higher bend angles for notched, slow-bend tests than a welding speed of 10 in. per minute. This holds true both for semikilled and fully killed steels.

In addition, Fig. 9 shows that a preheat of 400° F., gave much better results in the hatch corner tests. Not only was the ultimate unit strength increased by 7000 psi., but the energy absorption increased from 400,000 in.-lb. to 1,350,000 in.-lb. It seems here that the arresting of the cooling rate and the improved resultant metallurgical structure contributed to the better results.

Aging Improves the Notch Toughness of Welded Specimens

Some of the work at Battelle offers an explanation for a phenomenon noticed in weld testing. We are all familiar with the fact that the incidence of failure of weld bend specimens seems to be higher when the specimen is bent immediately after welding. Figure 11 depicts this rather well. It can be seen that the specimens which were aged 7 days gave better bend angles in the notched, slow-bend test. This might well be remembered when welder qualification tests are conducted.

Practical Conclusions Relating to Ship Construction

1. It has been rather well established that square hatch corners can fail at relatively low stresses in the neighborhood of 24,000 psi. Therefore this type of discontinuity should be avoided at all possible locations in the development of ship design.
2. Most of the improved designs, which have already

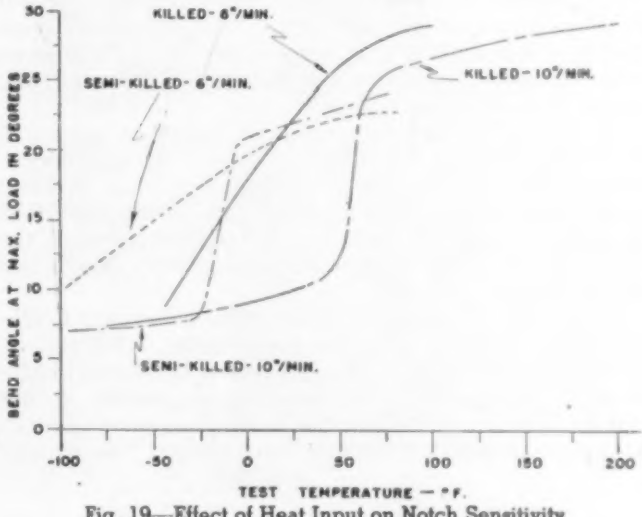

Fig. 19—Effect of Heat Input on Notch Sensitivity
From Stout, McGeady, Sun, Libsch and Doan

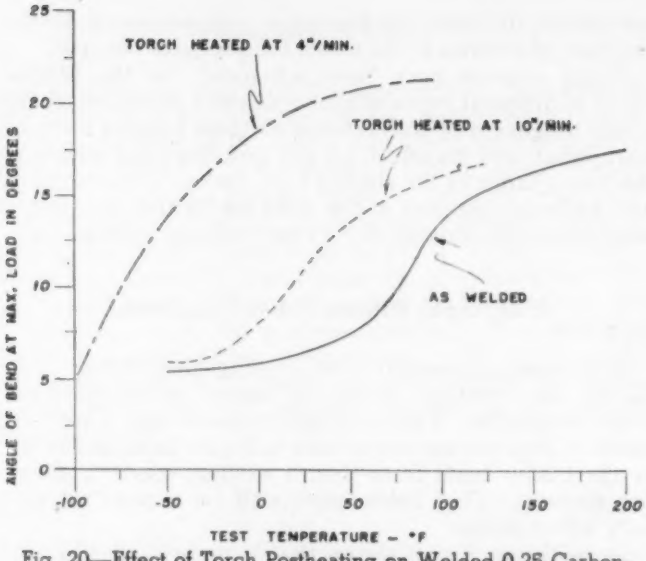

Fig. 20—Effect of Torch Postheating on Welded 0.25 Carbon-Silicon Killed Steel
From Stout and Mc Geady

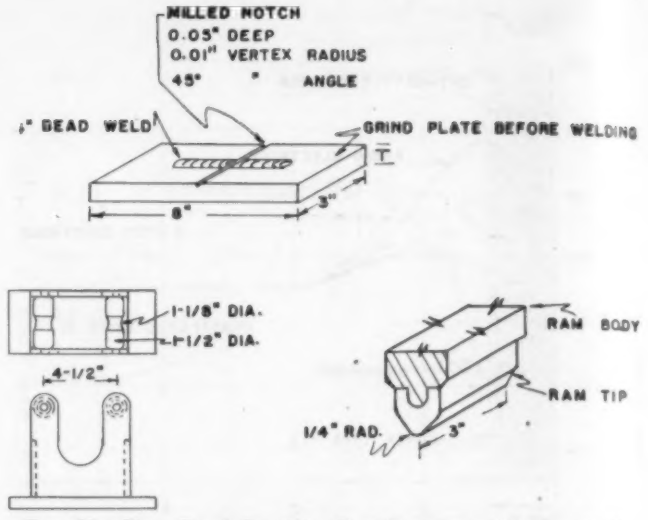

Fig. 21—Slow Bend Ductility Test Recommended by A. B. Kinzel

been applied to ships, maintain some aspect of the inherent square corner. Some individual characteristics of the square hatch corner design have been improved. In one case, improved performance was achieved by only extending the longitudinal coaming for one frame space, retaining the square hatch corner as such. In all of the altered designs, improvement is achieved because more favorable conditions were developed for the transmission of stresses by the avoidance of the full concentration of stresses at the square corner itself. In all cases, except the Kennedy design, a reinforcing doubler plate is proposed.

3. The most effective new design presented completely eliminates all characteristics of the square corner. This is the hatch corner designed by Harry E. Kennedy. Here, no doubler plate was fitted in way of the corner itself. Instead, a rounded corner was incorporated in the vertical and horizontal members. Complete ductile behavior resulted and the specimen failed at some distance from the corner.

4. Since thickness and size seem to have a detrimental effect where a notch effect exists, it may be advisable to start thinking in terms of reducing the thickness in way of discontinuities and compensating for it, by either the use of higher strength steels or by using increased sections in way of neighboring locations which do not possess discontinuities.

5. Riveted structures with discontinuities do not show greater ultimate unit strength than welded ones. But they do tend to absorb more energy. There is no basic difference between the behavior of riveted and welded structures under conditions of a notch effect.

6. Any of the above-mentioned changes in hatch corner design had a greater effect on improving their performance than any change in welding electrode, preheat, postheat and welding procedure. Therefore, regardless of the improvement of the notch toughness of steel, the effect of the notch must be eliminated from design and workmanship.

7. Semikilled ship steel has rather low notch toughness and ductility at room temperature. Efforts are being made to change the qualities of this steel in this respect. In addition, specifications, at present, do not call for a test to evaluate the notch toughness of steel. Many small tests are being considered. The general trend is in the direction of a slow-bend ductility test along the lines of the one proposed by Dr. A. B. Kinzel in Fig. 21. Evidence is available which indicates that this type of test would be able to fairly closely evaluate the ductility and resultant behavior of the steel structure under service conditions.

8. The act of welding to a certain extent impairs the notch toughness of steel. Methods are available which can restore this property to the steel. The most effective methods are preheating and postheating. Different types of electrodes also have some little effect on improving notch ductility.

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The Resistance-Welding Characteristics of the Dry Disk Rectifier Welder*

By C. E. Smith and R. H. Blair†

The paper consists of a general discussion on the electrical operation and electrical characteristics of the dry disk rectifier welder showing its method of obtaining direct current for welding and the wave shapes obtained by this method. The secondary wave shapes are rather new and novel in comparison to present 60-cycle frequency welding machines, in that the rate of rise of current is much slower, producing some very interesting results in the welding of certain materials. The advantages and disadvantages of the secondary wave shape and the self-regulating effect in spot, seam, projection, push butt welding of aluminum, low-carbon steel, stainless steel and other alloys are covered. This device with its 3-phase balanced load and high power factor not only makes it a very good correction device in lowering the kva. demand in comparison to the single-phase a.-c. machine, but also produces secondary wave shapes that are more desirable for welding of certain materials than that which is found in the simple, single-phase a.-c. machine wherein the rate of rise of current is controlled by the 60 cycle frequency.

Introduction

ENGINEERING investigation of 3-phase welding machines of the power factor correction type has been carried on by The Taylor-Winfield Corp. for over a period of six years. During the early part of this period, engineering thoughts were directed to accomplish a resistance-welding device to reduce the kva. demand and divide the primary current over the three phases of the power supply systems. The combination of greatly reduced power demand, 3-phase balanced load and high power factor diminishes the power charges, improves the line voltage regulation, minimizes light flicker, permits more or heavier welding from an installed power supply and equalizes power line currents and heating of power distribution equipment. Since the power demand of this type of welder remains essentially constant, regardless of throat depth, greater use can be made of welders with deeper throat depths and increased work clearances.

The purpose of this paper is not to describe the 3-phase dry disk rectifier machine as a correction device or its effect on the power supply system in comparison to other types of resistance-welding equipment, but to offer engineering information in regard to its application in the welding of certain materials, a discussion of the secondary current wave shape and the self-regulating characteristics of the equipment. General description of the rectifiers and the electrical characteristic of the dry disk rectifier machine is included.

General Description

The 3-phase dry disk rectifier power pack (magnesium-copper sulphide type) to produce the d.-c. secondary welding current replaces the conventional single-phase a.-c. welding transformer. The power pack consists of a 3-phase full-wave rectifier circuit and the rectifier transformers. Figure 1 is a photograph of a Tri-Phase dry disk rectifier machine, an R.W.M.A., Size 3 press welder.

Each rectifier stack consists of a group of heavy copper plates, like sections of bus bars, assembled together on bolts with disks of magnesium and disks of copper, coated

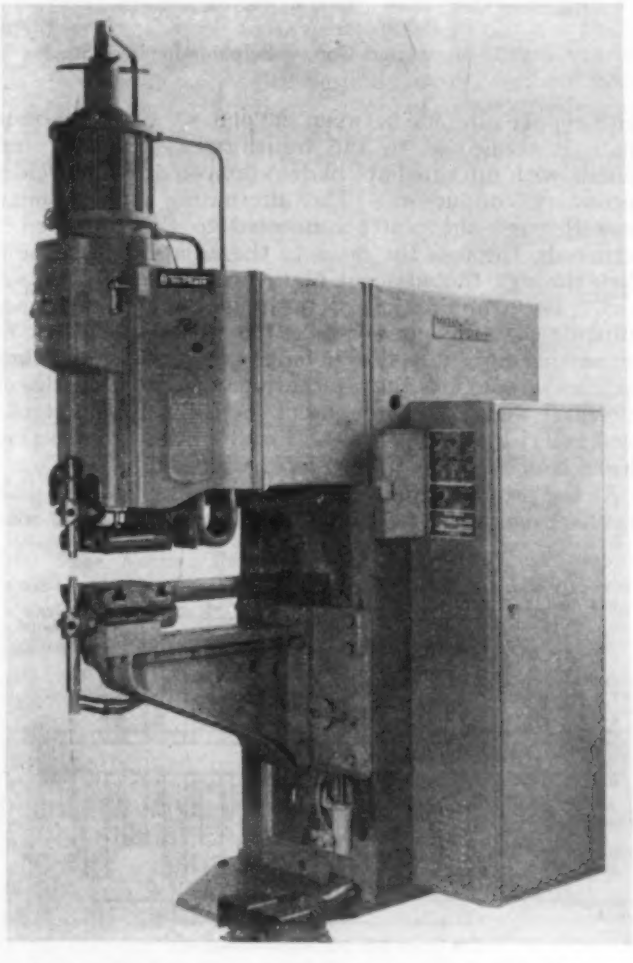

Fig. 1—Tri-Phase (Dry Disk Rectifier), Size 3 Press Welder

* Scheduled for Twenty-Ninth Annual Meeting, A.W.S., Philadelphia, Pa. week of Oct. 24, 1948.

† The Taylor-Winfield Corp., Warren, Ohio.

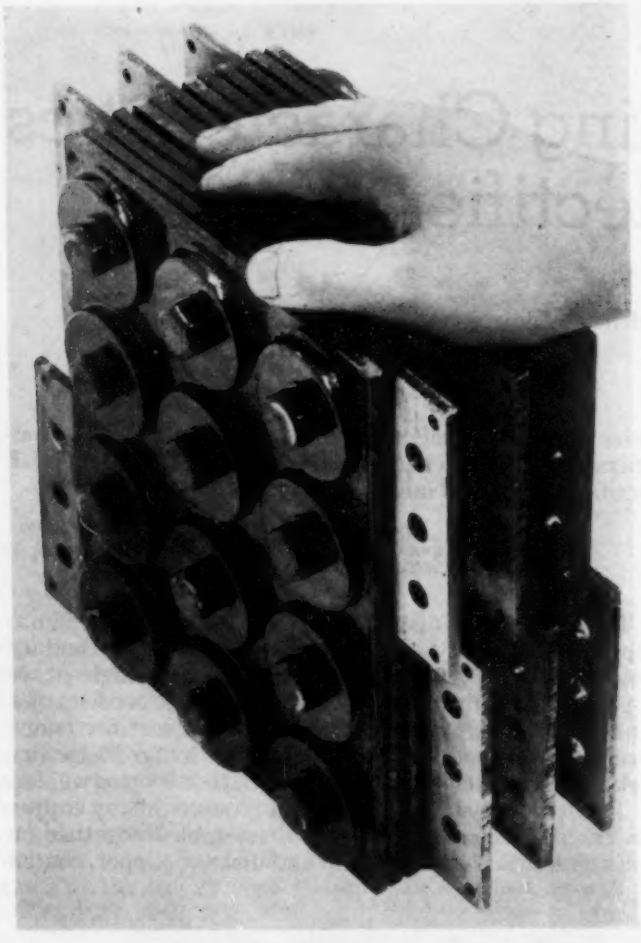

Fig. 2—Magnesium-Copper Sulphide Rectifier Stack

with copper sulphide between the plates. Each alternate plate is connected to the transformer secondary terminals with intermediate plates connected to the welder secondary conductors. The alternating current must pass through the plates connected to the transformer terminals, through the disks to the adjacent plates and then through the adjacent plates to the welder conductors. The combination of the magnesium and copper sulphide coated copper washers has the characteristic of permitting current to flow in only one direction, and thus rectifies or converts the alternating current to the direct current. Figure 2 shows one of the conventional stacks used in Tri-Phase welders and Fig. 3 shows a cross section through an assembly of the plates, disks, etc.

At the present time there are various types of dry disk rectifiers manufactured and it is worth while to give consideration to these various types of rectifiers in the application of welding machines in regard to current density, relative efficiency vs. temperature and per cent of rectifier life vs. operating temperatures.

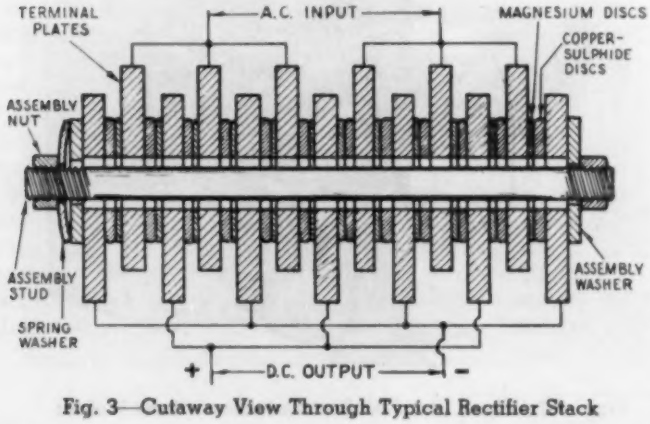

Fig. 3—Cutaway View Through Typical Rectifier Stack

1. Proper Analysis of the Efficiency.—A study of the low impedance curve and efficiency data will show that the efficiencies are lowest at low current and with low impedance loads. With a given load current, the efficiency will improve as the load impedance increases up to a point where the load impedance equals the rectifier impedance. In the resistance-welder applications, there is no object in attempting to operate the rectifiers at a maximum efficiency as long as the impedance adjustment must be in the load circuit, not in the rectifiers themselves. Figure 4 shows the relative efficiency of rectifiers vs. the operating temperature, of the copper sulphide (Mg-CuS), the selenium rectifier (Se) and the copper oxide rectifier (Cu_2O). The per cent relative efficiency is given on the vertical axis and the temperature in ° F. is given on the horizontal axis.

The application of the dry disk rectifiers in the Tri-Phase welding equipment is selected thermally so that the maximum temperature rise does not exceed standard specifications of permissible transformer temperature rises.

2. Current Densities.—Figure 5 shows the cell-current densities, continuous and intermittent operation, for the copper sulphide rectifier, the selenium rectifier and the copper oxide rectifier. The vertical axis is shown as the d.-c. amperes per square inch, giving the relative values of the various types of rectifiers and their ability to handle current density.

3. Per Cent of Rectifier Life Vs. Operating Temperature.—Figure 6 is a chart showing the per cent of normal life in the vertical axis vs. temperature in ° F. on the horizontal axis showing that the magnesium-copper sulphide rectifier is not influenced by temperature until the

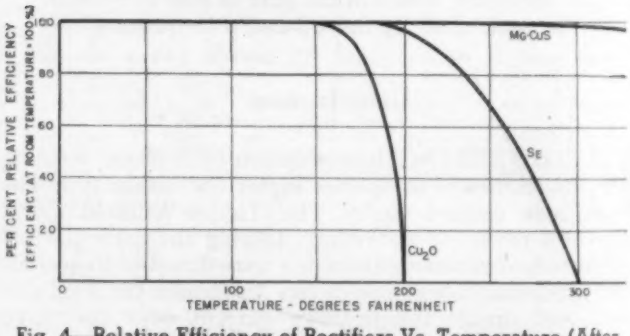

Fig. 4—Relative Efficiency of Rectifiers Vs. Temperature (After Approximately 5 Hr. at Each Temperature)

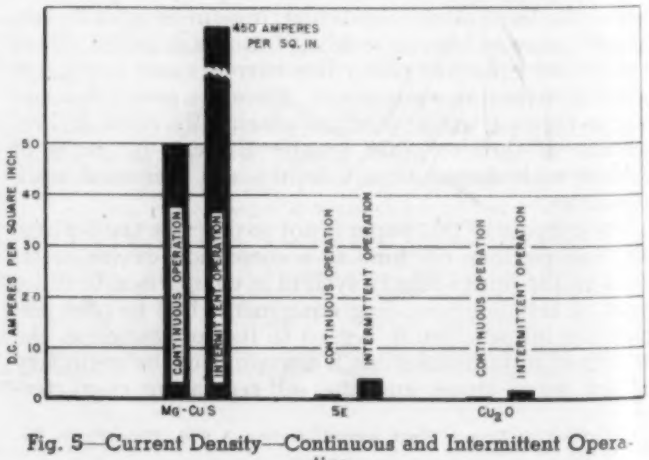

Fig. 5—Current Density—Continuous and Intermittent Operation

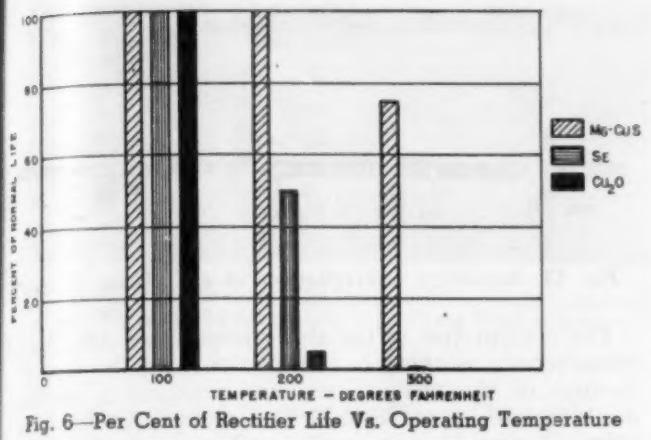

Fig. 6—Per Cent of Rectifier Life Vs. Operating Temperature

relatively high-temperature value of approximately 300° F. is reached.

4. Installation Record.—Figure 7 shows an installation record of heavy-duty magnesium-copper sulphide rectifiers from 1938 to 1946 vs. the rectifiers installed per year. The rectifier stacks installed per year will give the total of 140,000 rectifier stacks over a period of eight years.

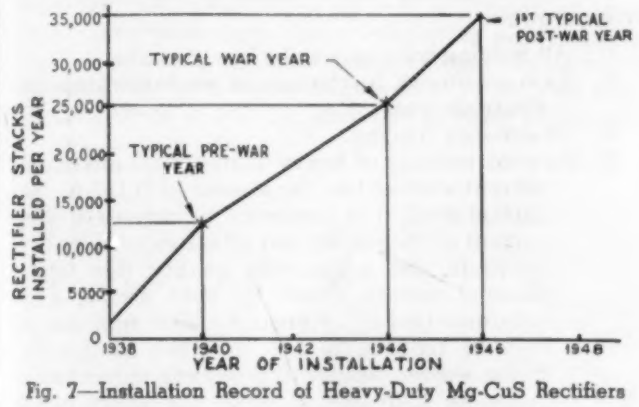

Fig. 7—Installation Record of Heavy-Duty Mg-CuS Rectifiers

5. Size of the Rectifier Stacks.—The size of the rectifiers in respect to the application of the three types of rectifiers has been given serious consideration. The magnesium-copper sulphide rectifier has been found to be of such physical dimensions that the power pack, complete with rectifier transformers, can be installed in a standard line of welding machines. Figure 8 shows a photograph of a completely assembled power pack ready for installation into the frame of the welding machine.

Electrical Characteristics of the Dry Disk Rectifier Machine (Mg-CuS)

Correction Factors

Curve *A* in Fig. 9 shows a typical ratio of single-phase kva. demand of the simple a.-c. welder to total 3-phase kva. demand of a tri-phase welder when producing the same welding current at each indicated throat depth. Curve *B* is a typical ratio of single-phase kva. demand of a simple a.-c. welder to kva. demand per phase of a triphase welder when producing the same welding current at each indicated throat depth. Figure 10 is an oscillograph showing the d.-c. welding current in the secondary of a Tri-Phase welding machine and the balanced

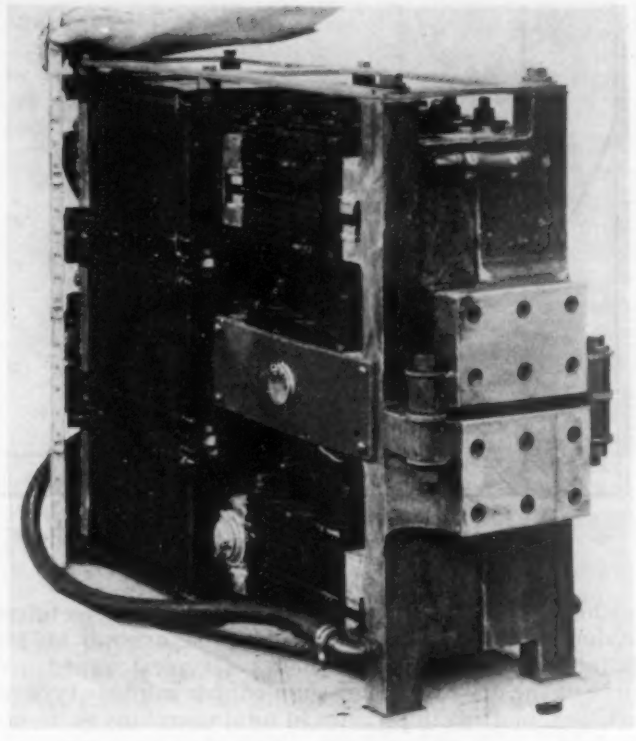

Fig. 8—Tri-Phase Power Pack (Mg-CuS Rectifiers)

3-phase a.-c. line current when making a typical weld.

Power Pack Impedance

Electrical design engineers are constantly confronted with the inherent limitations of all electrical apparatus and their application to a specific job. It often appears to the engineer that these various inherent characteristics are working against his desired results. Seldom does an inherent characteristic of a piece of apparatus appear to aid the engineer, but with the application of the magnesium-copper sulphide rectifiers to resistance-welding

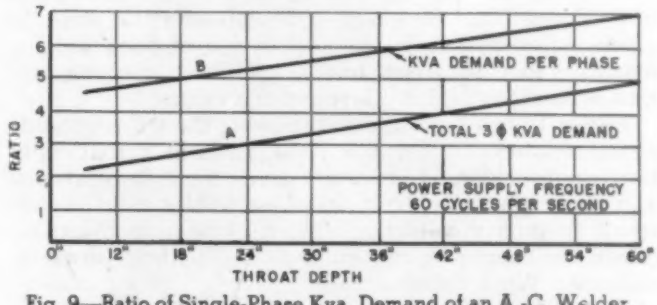

Fig. 9—Ratio of Single-Phase Kva. Demand of an A.-C. Welder, Uncorrected, to Kva. Demand of Tri-Phase Welder (Producing the Same Welding Current at Each Indicated Throat Depth)

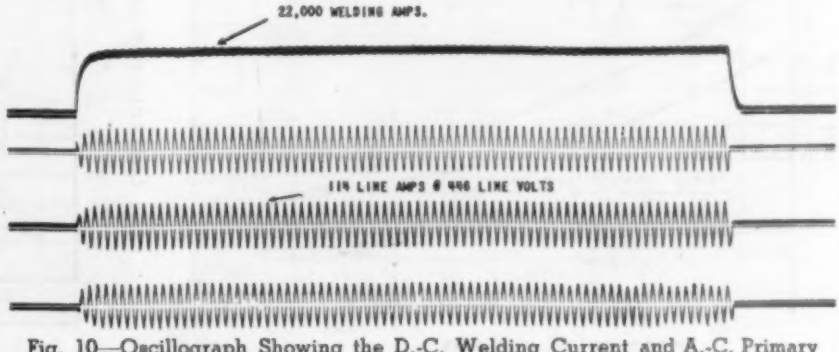

Fig. 10—Oscillograph Showing the D.-C. Welding Current and A.-C. Primary Currents Making a Weld of 0.187 to 0.187-In. Low-Carbon Steel

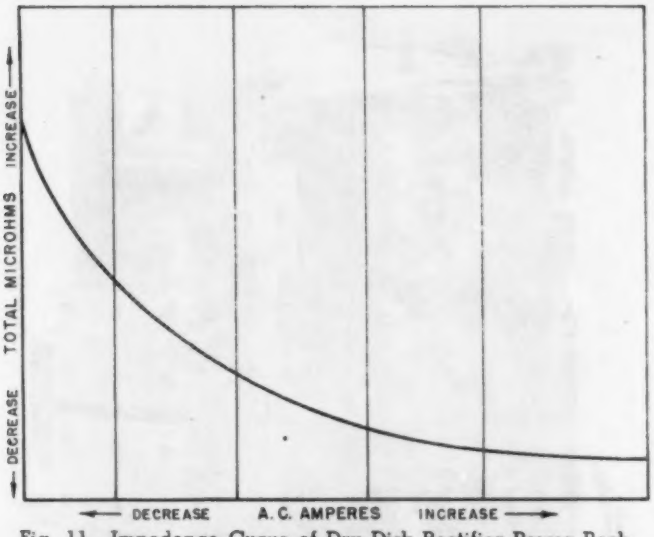

Fig. 11—Impedance Curve of Dry Disk Rectifier Power Pack (Tri-Phase Mg-CuS)

machines, the impedance characteristics of the rectifiers produce the seldom found but desirable over-all welder characteristics. Figure 11 shows a typical impedance curve of the dry disk magnesium-copper sulphide type of rectifiers, plotting impedance in total microhms vs. thousands of a.-c. (rms.) amperes. Note that the copper sulphide rectifiers possess a negative resistance characteristic which greatly benefits the application of the welding machine in regards to a self-regulating characteristic that is described in the next paragraph.

The Self-Regulating Characteristics of the Tri-Phase Welding Machine and the Effect of Work Resistance

Like all high-power factor devices similar to the series-capacitor power factor corrected single-phase machine and the 3-phase electronic frequency converter machine, the tri-phase dry disk rectifier welder is resistance limited. Therefore, more care must be taken in concentrating resistance in the work by making the welder resistance as low as possible. However, this characteristic must be given consideration in the application of such welding machines in comparison to a single-phase a.-c. machine that is handling high work-resistance values.

Figure 12 is a typical chart showing the self-regulating characteristics of a Size 3, R.W.M.A., 36-in. throat depth press-spot welder. Curves are given for a conventional a.-c. single-phase welder, a tri-phase welder and the electronic frequency converter welder. The ratio values indicate the change in current with and without work resistance. Work resistance 108×10^{-6}.

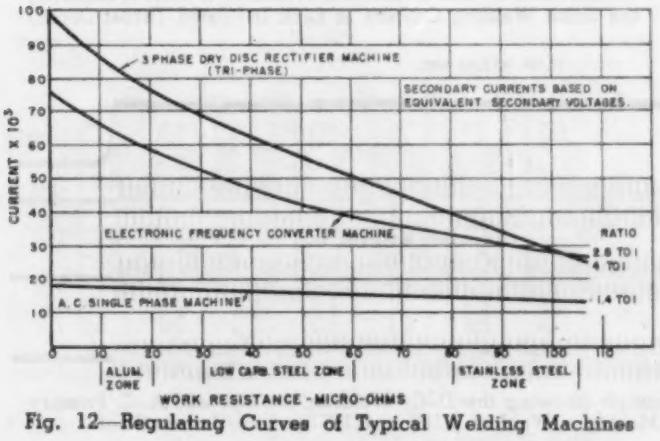

Fig. 12—Regulating Curves of Typical Welding Machines

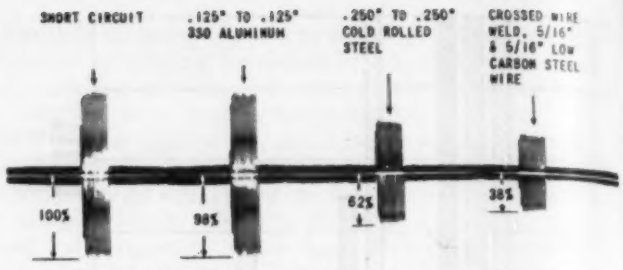

Fig. 13—Regulating Characteristics of a Tri-Phase Welder

The combination of the above power-pack impedance characteristic working in conjunction with the d.-c. resistance of the welding machine produces a welding machine with very desirable self-regulating characteristics. Figure 13 is an oscillograph showing the effects of the regulating characteristic of a 3-phase dry disk rectifier machine when making three welds on the same transformer tap setting and three different materials, 0.125 to 0.125 3So aluminum, 0.250 to 0.250 cold-rolled steel and cross wire, $^5/_{16}$- and $^5/_{16}$-in. low-carbon steel wire. When welding aluminum, the current was 98% of short circuit; when welding the cold-rolled steel, 62%; and when welding the carbon steel wire, 38%.

The self-regulating characteristic of the welding current permits:

1. All welding schedules to be less sensitive.
2. Less sensitivity to changes in work thickness and electrode wear.
3. Closer spot spacing.

In the spot welding of heavy material on alternating current such as two thicknesses of 0.187-in. low-carbon steel, it is necessary to increase welding current of the second and all subsequent spots to maintain the same weld quality due to the shunted current, unless the spot spacing is approximately 3 in. or greater. This spot spacing may be reduced to $1^1/_2$ in. when using a Tri-Phase welder because the welding current automatically increases to offset the effect of the shunting current.

This self-regulating characteristic is amplified by the change in impedance of the rectifier itself (inverse resistance). As the work resistance becomes lower in value, the current increases accordingly.

Due to its wide resistance conscious load circuit, the dry disk rectifier machine does not require electronic phase shifting heat control apparatus for heat control of weld. Figure 14 is a chart showing the tap switch settings vs. per cent heat control (when measured under dead short characteristics, without work).

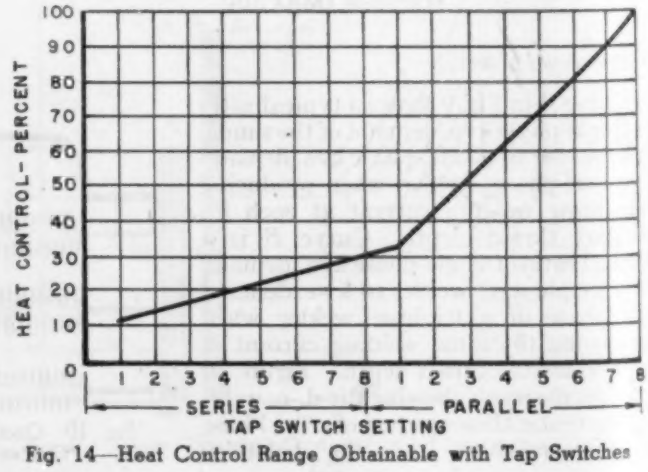

Fig. 14—Heat Control Range Obtainable with Tap Switches

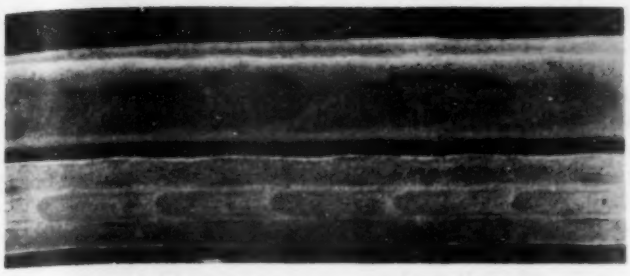

Fig. 15—Heat Distribution. Tri-Phase and Frequency Converter Seam Welds (0.064 Aluminum). Tri-Phase Weld at Bottom

The Wave Shape of the Direct Current

Figure 10 is an oscillograph showing the rate of rise of current, maximum current determined by the E over R of the secondary circuit. The rate of rise of current is found to be normally faster than the usual R and L load circuit with a stiff power supply. The impedance characteristics of the rectifiers tend to change the total load circuit making the initial rate of rise of current slightly faster. The dynamic resistance is greater than the static resistance, and thus the resistance is greater at lower loads. The secondary direct current is nonreversible, that is, the polarity of the current is the same on all welds. The direct current, without reversal of polarity or without the change in current from one polarity to the next that is experienced in circuits of reversing polarity, produces a more constant 3-phase kva. load.

The desirable nonreversing d.-c. welding current is advantageous for the following reasons:

1. The value of the welding current remains essentially constant as magnetic work or fixtures are moved into or out of the welder work area, or as the welder work areas are changed.
2. The power demand of deep-throat welders is only slightly increased over the power demand of short-throat welders of the same welding current output. Any slight increase or decrease is due to minor changes in the secondary circuit resistance.
3. Better current and heat distribution in the work is obtainable in many cases when using direct current. Better heat distribution is obtained in welding of heavy current welds and welds where the weld area is widely distributed (such as a large ring type of projection welds).

   An illustration of heat distribution is shown in Fig. 15. Note the uniformity of the fused zone of a d.-c. weld made by seam welding with a Tri-Phase welder as compared with a weld made using an electronic frequency converter with its welding pulses of alternating polarity. The weld nuggets move out of true centerline with each impulse.
4. Reduced electrode wear and electrode pickup as well as reduced work surface burning is obtained when using a Tri-Phase welder.

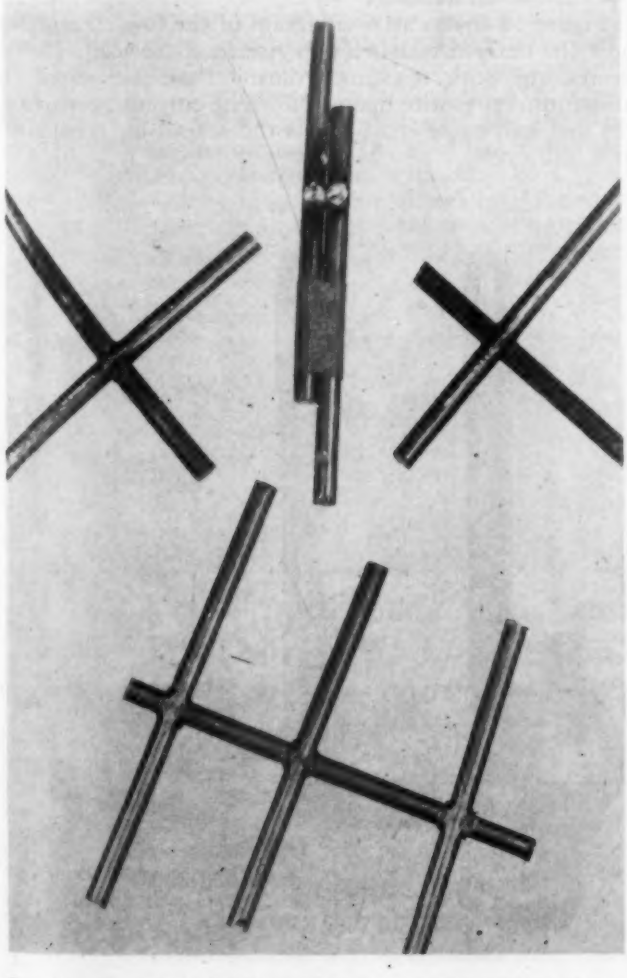

Fig. 16—Cross Wire Welding of Aluminum Rod with Tri-Phase Welder

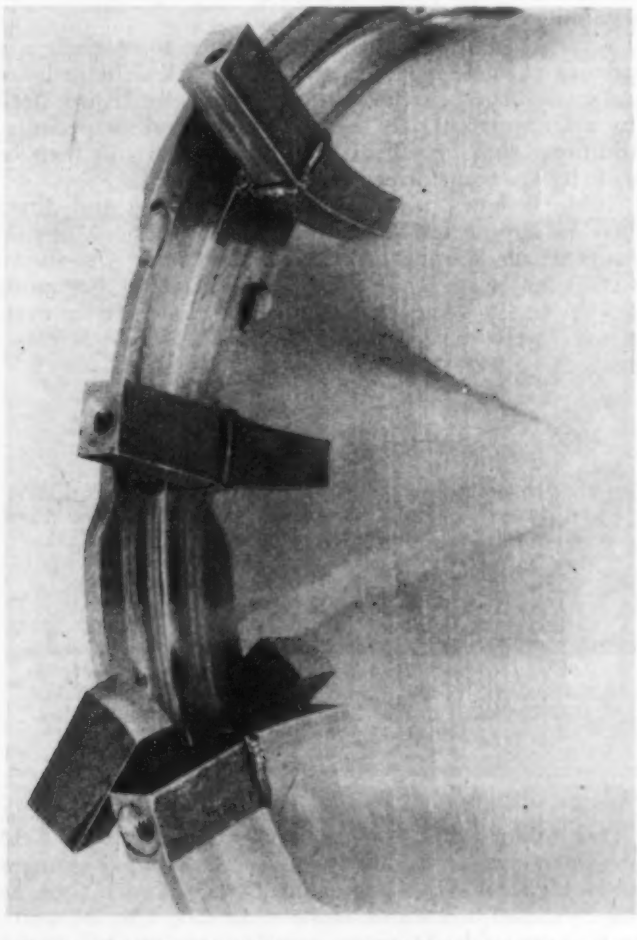

Fig. 17—Photograph of Aluminum Stud Weld to the Side of a Pressure Cooker

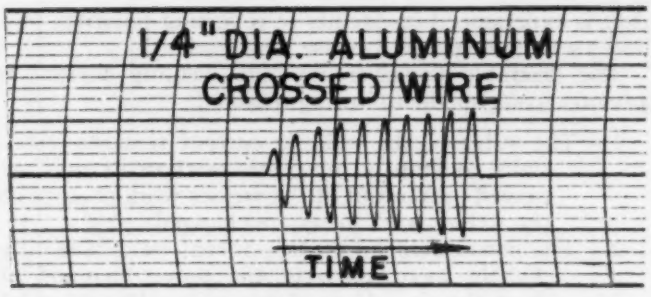

Fig. 18—Primary Current Trace Showing Compensation for Decrease in Work Resistance in Aluminum Cross-Wire Welding

Welding Characteristics

The setting up of weld schedules on the Dry Disk Rectifier Welder is a simpler operation for many types of work pieces than is the case on a single-phase machine with 60-cycle welding current. There are even some welding operations that were found to be easily done on the dry disk rectifier machine and could not be performed on the 60-cycle machine. Reasons for this difference can be found for one or more in the following statements:

1. The d.-c. wave, having practically a negligible ripple content, has almost a unity ratio of peak to rms. current. This reduces peak instantaneous temperatures at localized spots and reduces the tendency for weld spitting.

2. The d.-c. wave has a relatively low rate of rise, being usually 2 to 4 cycles in length depending on the *R* and *L* machine characteristics, and thus maintains the faying surface temperatures below spitting temperature values during the period of high-contact resistance at the beginning of weld time.

3. The addition of work impedance to machine impedance is made in phase with the machine impedance and causes the heat level to automatically adjust itself (to a large extent) to the particular work impedance. Additional and final heat level adjustment can then be made by the transformer tap selector switch.

Table 1 shows peak values of alternating and direct currents having the same final rms. values. Measurements are made from the start of weld time. Also shown is the ratio of a.-c./d.-c. peak watts from the beginning of weld time. Note that during the first quarter cycle of weld time, peak instantaneous watts are 24 times greater on alternating than on direct current.

Table 1

Time from Start of Weld, Cycles	Peak Amperes A. C.	Peak Amperes D. C.	Ratio of Instantaneous Watts, A. C./D. C.
1/4	1.41	0.285	24.5
3/4	1.41	0.524	7.25
1 1/4	1.41	0.667	4.46
1 3/4	1.41	0.761	3.43
2 1/4	1.41	0.837	2.84
2 3/4	1.41	0.882	2.56
3 1/4	1.41	0.927	2.31
3 3/4	1.41	0.960	2.16
4 1/4	1.41	1.0	2.00

This table indicates that on certain types of weld jobs—namely, those jobs whose work resistance changes from a high value to a low value during the weld time, as well as those jobs whose work resistance may be quite erratic from piece to piece—considerable trouble would be found in using a.-c. equipment. This trouble would be in the form of spitting, blowouts or lack of setdown in the case of projections.

Two examples to illustrate this effect are shown in Figs. 16 and 17. Figure 16 shows cross-wire welds made in 1/4-in. diam. aluminum rod on both 30-in. throat a.-c. and dry disk rectifier machines. The d.-c. welds could be made consistently and repeatedly and set down a full 100%. On the a.-c. welding of this material, it was very seldom possible to make a weld without a work explosion. If the heat of the a.-c. weld was set sufficiently high to acquire the full setdown, the work would explode during the first cycle of heat time; if the heat were set low enough to prevent the explosion at the start of weld, the heat level then was too low at the end of the weld time to acquire the full setdown. In this case it was found impossible to fit a highly changeable work resistance into a practically fixed current level and obtain good results. On direct current, the current changed inversely as the work resistance and kept the rate of heat input to the work more nearly constant.

This same effect was evidenced in the welding job of Fig. 17. Here a 3/8- x 1/2-in. aluminum stud was welded to the side of a pressure cooker. Prior to doing the work on the dry disk rectifier machine, the job was handled in an a.-c. machine where the current level was kept low enough to prevent the blowout and consequently was too low to get the desired setdown. Therefore, the a.-c. weld merely served as a locator after which a bead was made around the stud with a hand torch resulting in surface discoloration, annealing of the metal around the stud and high labor cost. Customers' test results show that the straight d.-c. projection weld had 50% more strength than the previous welds made under a combination of a.-c. and torch welding.

Figure 18 shows an oscillogram of the line current and how the current continues to rise to compensate for the decreasing work resistance during the setdown of the aluminum cross-wire operation. The current here during the last half cycle is 2.6 times the amplitude during the first half cycle.

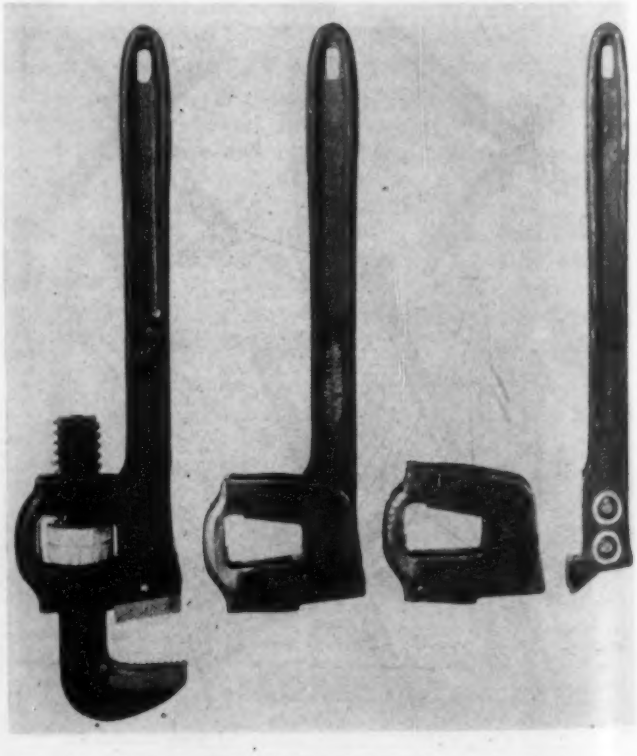

Fig. 19—Photograph Pipe Wrench Assembly. Two Projections of 7/16-In. Diam. Welded Simultaneously

Fig. 20—Primary Current Change When Welding the Pipe Wrench Assembly

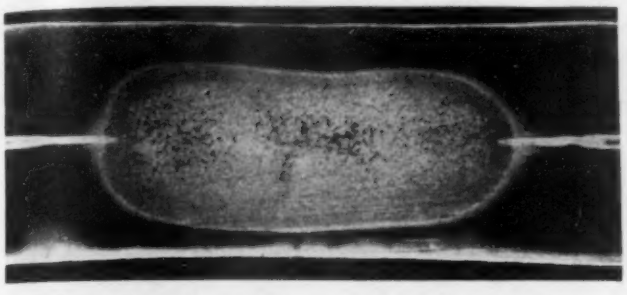

Fig. 21—Spot Weld in 0.156 to 0.156 24ST Alclad Aluminum. Weld Time, 18 Cycles. Total 3-Phase Demand, 385 Kva.

Figure 19 shows a pipe wrench assembly in which two projections of $^{7}/_{16}$ in. diam. were welded simultaneously. The accompanying oscillograph chart, Fig. 20, shows the line current changing from 240 amp. at the start of weld to 400 amp. at the end of weld or at the end of 137 cycles.

Besides providing less critical weld schedules on d. -c. than on a.-c. welding, additional advantages are very evident from the d.-c. wave shape characteristic and current correction (self-regulating) characteristic of the dry disk rectifier machine. Since there is much less tendency for weld spitting on direct current, lower electrode forces may often be used on d.-c. welding. In many cases the electrode force can be reduced to 50% of the a.-c. schedule to give a well-defined center of heat at the weld and less heating of the metal outside the weld but in the current path. This also means that a machine of a given mechanical capacity can handle larger welding jobs when operating on direct current than when operating on alternating current, providing neither machine suffers any current limitation handicap.

Fig. 22—Spot Weld in 0.125 to 0.125 Stainless Steel. Weld Time, 19 Cycles. Total 3-Phase Kva. Demand, 53

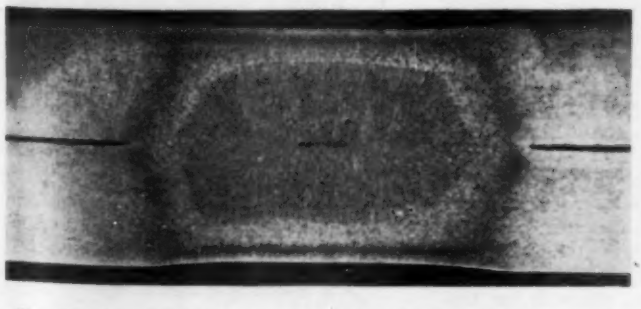

Fig. 23—Spot Weld in $^{3}/_{16}$ to $^{3}/_{16}$ Mild Steel. Weld Time, 79 Cycles. Total 3-Phase Kva. Demand, 87

Fig. 24—Spot Weld in 0.040 to 0.040 24ST Alclad Aluminum. Weld Time, 4 Cycles. Total 3-Phase Kva. Demand, 122

It should be noted with considerable significance that a forging force finds many more applications on the dry disk rectifier machine than on the a.-c. machine, especially where any type of projection welding is done. The characteristics of the dry disk rectifier machine, used with forging force, provide reduced initial forces and drastically reduce the 3-phase kva. demand below the required kva. demand when using single force.

From the oscillographic recordings of the welding current of the rectifier welder, it is seen that no zero current gaps exist and that the weld current can be maintained continuously to the full limit of the weld timer. This is quite important for it has been found that during multiple impulse welding with d.-c. or with any wave requiring a periodic cool time, a part of the succeeding impulse is utilized in regaining the weld temperature that was present in the weld at the end of the preceding impulse. The part of the succeeding impulse required to supply the weld temperature lost during the cool period amounts to approximately $1^{1}/_{2}$ times the length of the cool period. Therefore, to do a given welding operation in a given weld time under both conditions of continuous direct current and impulse, it is found that the d.-c. impulse current must be raised in amplitude and the kva. demand raised above that for the continuous d.-c. wave. This higher amplitude for the multiple-impulse direct current increases the probability of weld spitting on the first impulse. To equalize initial spitting probability, it is necessary to raise the electrode force on the impulse weld and this in turn aggravates the increased demand.

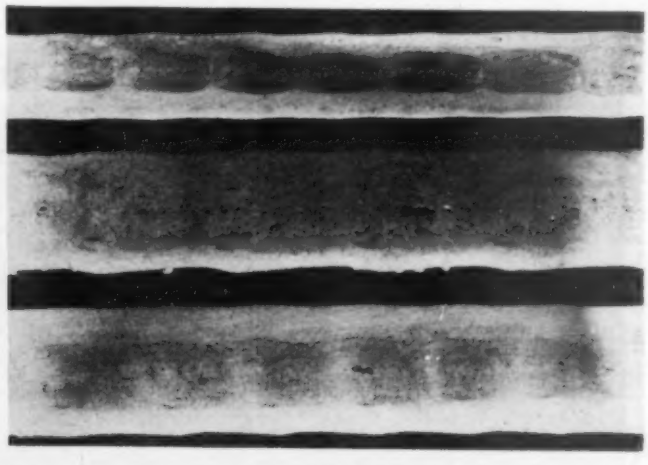

Fig. 25—Continuous Seam Weld in Two Pieces 0.091 61ST Aluminum; Two Pieces 0.064 61ST; Three Pieces 0.064 61ST. Weld Speed, 36 In. per Minute

Fig. 26—Continuous Seam Weld in Two Pieces 0.035 R301 Aluminum. Weld Speed, 60 In. per Minute

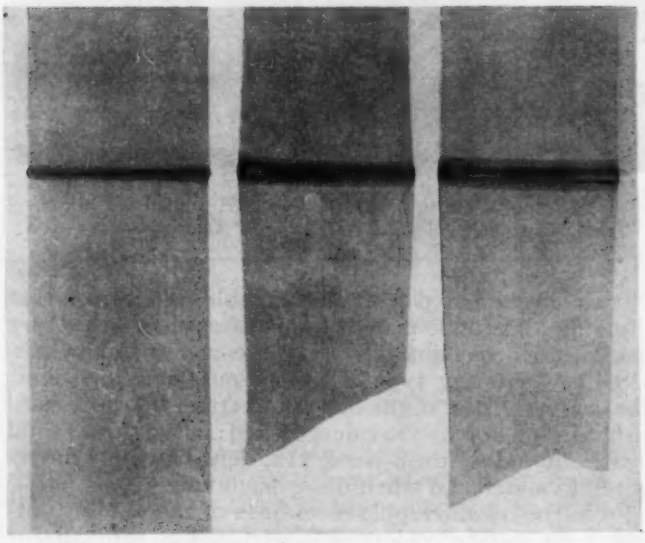

Fig. 27—Mash Line Projection Weld in Two Pieces 0.032 × $2^{11}/_{16}$ Electrolytic Zinc Coated Steel. Note: The Complete Edge Weld in the Two Samples Tensile Tested. Weld Time, 30 Cycles. Total 3-Phase Kva., 222. Tensile Test, 4050 Lb.

A continuous current wave is quite important in welding aluminum and other high conductivity materials where there is very little lag between current and weld temperature.

Disadvantages of 3-Phase Direct Energy Equipment

Like the electronic frequency converter machine, like the series-capacitor power factor corrected welder and like the conventional single-phase machines, the dry disk rectifier machine is a direct energy type of machine securing its energy directly from the power supply system. Unlike stored energy equipment such as the electrostatic (capacitor), the electromagnetic and the electrochemical (battery) types, energy into the weld will be changed with the changes in line voltages. This is particularly true when a fluctuating line voltage on all three phases is experienced. However, regulation created by single-phase welders will not effect 3-phase welders as much as single-phase welders will affect other single-phase welders.

When welding times of less than 19 millisec. ($1^1/_6$ cycles at 60 cps.) are required, the load will only commutate over two phases and will create an unbalanced 3-phase load, but such a load is in no way detrimental to the welding current.

Photomacrographs of Various Material Welded with Tri-Phase Equipment

Figures 21 up to and including 27 are a number of photomacrographs of various materials with accompanying data on weld time, phase kva. and total kva.

Summary

The discussion on this subject shows that dry disk rectifier machines, with proper engineering selection of the correct type of rectifiers, have excellent welding characteristics. The application of this type of welder may have merits over the simple single-phase a.-c. machine, but, in general, the single-phase a.-c. machine is still the machine to recommend when the power supply is adequate and welding requirements are no more exacting than average.

NOTES: Figures 4, 5 and 6 were obtained from P. R. Mallory & Co., Inc. Figures 4 and 6 are the results of an engineering project under government contract issued from Wright Field for the purpose of determining the characteristics of the Mg-CuS, Se and Cu_2O rectifiers. Figure 5 is the results of a study of published information on the three types of rectifiers.

Training Welding Technicians on a College Level*

By Richard C. Wiley†

The author issues a challenge to industry to assist the college in laying out a better course of instructions which will meet the needs of industry. He outlines the various courses of training available in the college.

A CLOSE relationship must exist between industry and our educational institutions if both proper training of the individual and growth of the industry are to take place. In case you have not thought of this before, any information that you may give to aid schools in formulating programs will come to be of great benefit to your own company. Consider only a few of these: Less on-the-job training is required where adequate pre-training has been given. A wider use of products results from increased knowledge of their application. For example, when an agricultural engineering student learns the uses of welding it is doubtful if he will consider any other means of fabrication or repair. In addition, a college-level program is healthful for the industry because it adds to the pool of trained men.

Unfortunately, schools tend to lag behind industry mainly because of their sheltered nature. Also, there is far too little cooperation in the matter of specific need given from industry itself. You men are all from the welding field: engineers, supervisors, salesmen and others in allied industries and jobs. As I go through this paper, I would like to have you keep in mind these points.

1. Would a student with the training we have given him qualify for work in your company?
2. On what level could he be employed?
3. Is there anything lacking in the courses given which should be included?

To sum up the situation, if industry tells us what it wants in the way of technicians, we will do our best to send industry valuable men.

Methods of Instruction

California State Polytechnic College, located at San Luis Obispo, is interested in

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* A paper presented before the San Francisco chapter of the AMERICAN WELDING SOCIETY, May 24, 1948.

† Welding Dept., California State Polytechnic College.

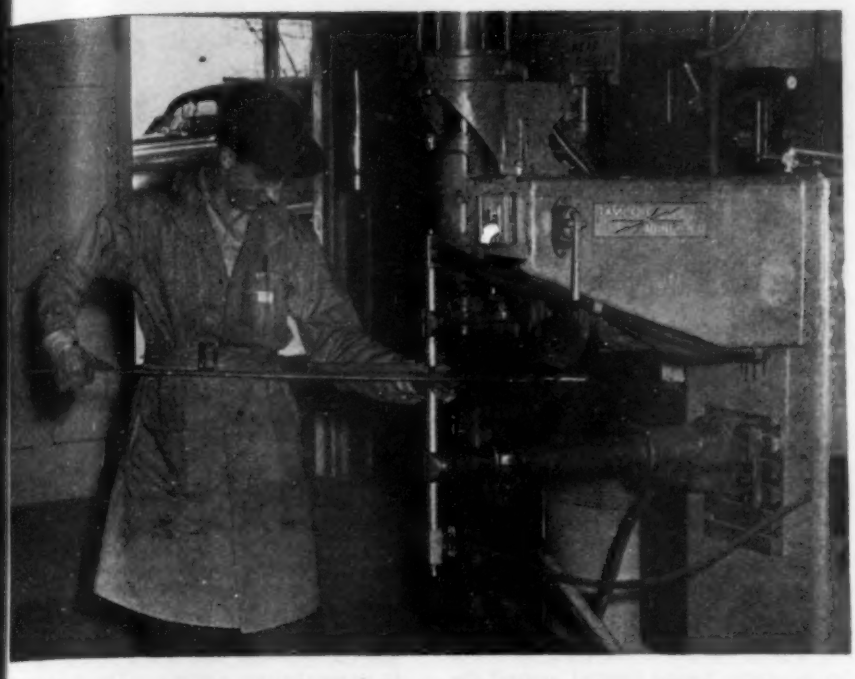

Fig. 1—75-Kva., Air-Operated, Electronic-Controlled Resistance Welder. Student Shown Operating the Machine

carrying out the responsibility of providing its 2200 men students with an agricultural and mechanical arts type of education on a college level. This school is unique among colleges in that it uses a project system of instruction which incorporates the philosophies of "learning by doing" and "earning while learning." Major emphasis is placed upon instruction rather than on research. California Polytechnic college operates on the system known among educators as the "upside down" plan, which is characterized by the grouping of as many technical and job-getting courses in the first two years as possible and then continues on to award a Bachelor of Science degree. Thus, a student may, if necessary, terminate his college work anywhere along the line and still be prepared to handle a job in agriculture or industry without loss to himself or to society.

The teaching of welding is no exception to this general pattern and it fits itself readily into the total program of the college. By looking into the setup of this school there may be seen the versatility of the application of welding to a considerable variety of college-level subject.

The two main divisions of instruction at California Polytechnic College are in agriculture and industry. The agricultural division operates a completely stocked, 2000-acre ranch which is equipped with the latest in farm machinery ranging from corn pickers to mechanical post-hole diggers. The repair and some of the special fabrication of this equipment is done by welding wherever indicated. Our farm students are not learning to be baling wire mechanics.

The industrial division is made up of five main groups: mechanical engineering, electrical engineering, aeronautics, air conditioning and architecture. As an applied example of the "learning by doing" method of instruction in the industrial branch, the electrical engineering department installs, maintains and repairs all electrical equipment used on the campus. Recently a 75-kva. air-operated, electronic-controlled resistance welder was installed by electrical engineering students for the welding shop. The mechanical engineering students operate a Diesel electric-power-generating plant which supplies part of the school's electrical energy requirements. Similar undertakings are carried on by the other engineering departments to give students first-hand practical knowledge of what industry will expect of them on the job.

Welding serves both the agricultural and industrial divisions of the college as an important related subject. The main function of the welding department is to familiarize students with welding techniques and uses and not to train welding operators. Fundamentals are presented during the first two years with the basic skills being gained by actual practice. In short, every student who takes our courses learns how to weld. He is then taught the special applications to his own field. During the third and fourth year, advanced courses in welding design and engineering are given. The welding department, then, is in a position in which it must give instruction on every level and in the majority of the welding processes.

Facilities for Teaching Welding

In order to carry out such a program it is necessary to have a well-equipped shop and attendant facilities. The main shop building is 40 x 100 ft. with a welding engineering laboratory, an office, an experimental testing laboratory and a shop area. Connected buildings are occupied by toolroom, stockroom and locker-room. Two acetylene generators of a combined 450-lb. carbide capacity are housed in a separate building. The acetylene is piped to the welding stations from there. The oxygen manifold system and oxygen storage are located in an elevated warehouse for ease in loading and unloading cylinders.

The main instruction shop is equipped with thirty oxyacetylene welding stations having both the light aircraft-type and the heavy-duty, all-purpose welding torches. Individual regulators for pressure adjustment accommodate each station. In the arc-welding section there are 14 stations separated from the rest of the shop by a flash screen. The welding generators and transformers are banked at each end of the booth section for

Fig. 2—2500-Lb. Capacity Welding Positioner in Use. Work Mounted on the Positioner Is the Arch Section of a 150-Ton Press Being Altered to Suit Shop Requirements

optimum space-saving purpose. A demonstrating area is also provided. Adequate ventilation is achieved by means of individual flexible tube fume collectors which are connected to the main header and a 5000-cfm. blower which exhausts the fumes outside. This entire exhaust system was designed, built and installed by students of the welding department.

Special equipment in the shop includes an atomic-hydrogen arc welding machine, a 75-kva., air-operated, electronic-controlled resistance welder (Fig. 1), a 1200- and a 2500-lb. capacity, variable-speed welding positioners (Fig. 2), a 300-amp, gasoline-driven portable arc welder, a 150-ton hydraulic press for physical testing and hot and cold forming, an inert-gas-shielded arc welder using both d.-c. and a.-c. high-frequency current, and an automatic submerged melt arc-welding head. Other ordinary shop equipment includes grinders, hand-operated shears, flame-cutting equipment, air hammers, a power hacksaw and miscellaneous hand tools.

The welding engineering laboratory (Fig. 3) is equipped with several large drafting tables, a number of drafting machines, a Spencer metallurgical microscope, a specimen-mounting press and polishing wheels, an electric furnace, a Rockwell hardness testing machine, a contact pyrometer and other ordinary laboratory apparatus and supplies.

These shop and laboratory facilities enable the welding department to give instruction designed to fit the particular needs of agricultural and industrial majors.

The Training Program

In a two-year program for agriculture engineering students, 3 hr. per week are spent during the first two quarters of their welding course on the fundamentals of oxyacetylene welding. Their activities are concerned mainly with work on light materials from 12- to 20-gage sheet. Brazing is also included at this time. The third, fourth and fifth quarters are devoted to arc welding with particular emphasis on the smaller farm-type a.-c. transformer welders and a.-c. machines. The types and uses of various electrodes, such as nickel electrodes for the welding of cast iron, are carefully considered. Problems of expansion and contraction are also observed. Improvement in welding technique is continually stressed. The sixth quarter consists of work in the welding engineering laboratory dealing with cost estimating and simple design problems. Stock and tractor trailers, self-built portable arc-welding rigs, and other projects of farm machinery are carried on to apply both practice and theory combined into a useful implement.

As more and more farms have electric power available under rural electrification programs, the use of the arc-welding transformer is increased. Particular concern is paid to this recent development because of the value of welding to farmers. During harvest period, for example, the speedy repair of a breakdown in equipment can mean the difference between failure and success. Portability of the a.-c. welder, although limited, is another desirable feature gained with the installation of plug outlets in the farm shop and also in pump houses located around the ranch or farm.

Fig. 3—A General View of Part of the Welding Lab Drafting Room. These Men Are at Work on Various Design Problems of Piping and Plate Fabrication

The aeronautic students complete a two-year oxyacetylene welding course made up of work in light alloy steel tubular construction as found in aircraft fuselage. The first three quarters consist mainly of fundamentals and practice on light sheet. Since aircraft repair work requires high quality welding, the importance of good technique is carefully developed in the students from the start. The fourth, fifth and sixth quarters deal with advanced aircraft welding including work with alloy steel tubing, aluminum and stainless steel. Problems in resistance welding are also considered. Because aircraft mechanics are required to pass the CAA examination before becoming licensed, practice in the CAA approved joints and splices form most of the work in the final period.

Students in college-level airconditioning and refrigeration take a two-year program in oxyacetylene welding. The first year deals with the fundamentals on light sheet and tubing. One of the projects of the first year is the layout and fabrication of a four-piece turn in 2-in. pipe which is pressure tested to 175 psi. upon completion. It is a minimum requirement of the course that the project withstand such pressure. During the fourth, fifth and sixth quarters more complex pipe joints are laid out and fabricated including 'Y's, reducers, orange peel heads and branch connections in various size pipe. These projects are tested to 2000 psi. Again as a minimum requirement the projects must withstand the applied pressure. Silver brazing and bronze welding are also included. A study of pressure piping codes and other welding codes are likewise considered.

Although it might appear on the surface that electrical engineering students have little use for a practical knowledge of

Fig. 4—An Over-all View of the Completed Backstop with Wire Hung in Place. Center Section Is 25 Ft. High, the Wing Sections Are 15 Ft. High. Veteran Student Housing Units in Background

elding, yet we enroll a number of men om this field. The ability to build pecial types of frames, temporary switch-oard and mountings is invaluable to lectrical technicians. Other miscella-eous groups also take a general welding ourse. Why animal husbandry or orna-ental horticulture majors would want o take welding is sometimes hard to e. However, the building of gates and ull pens from steel tubing and frames, pecial tools and racks from angle for use round a nursery are examples of applica-ion of these seemingly unrelated fields.

The mechanical engineering majors are he students who will be most likely to o from our department into the welding ndustry. In the first three quarters they ollow a fundamental arc-welding course imilar to that discussed under the agricul-tural section. During the fourth, fifth and sixth quarters work is carried on in the welding engineering laboratory dealing with problems in cost estimating, design of simple weldments, utilization of the standard welding symbols, introduction to the use of various welding codes such as the A.P.I.-A.S.M.E. Code for Unfired Pressure Vessels and the fundamentals of joint design. A project at this point is the design, complete specifications and cost estimate of an unfired pressure vessel to be fabricated in accordance with the A.P.I.-A.S.M.E. Code. This type of project serves to give the embryonic weld-ing technician a realization of the existance and importance of welding codes.

Courses have been set up covering the third year to deal with specialized welding processes and also to give fundamental metallurgical information. The content of these courses includes assignments in the study of the theory and in the actual use of automatic submerged melt arc welding, also inert gas shielded arc welding and the design of products for the use of resistance welding. Fabrication of proj-ects best suited to the use of these special processes are completed at this time. As an example, test plates from the sub-merged melt machine are made and tested mechanically. Specimens are also mounted and observed under the micro-scope to check physical properties of the weld metal and the base metal in this and in all other projects undertaken.

The program for the fourth-year me-chanical engineering students consists of machine design strictly from the welding viewpoint. The application of flanging and pressing to weldments is studied and also carried on in a reduced scale. Fur-ther studies of composite weldments using steel castings, plates and shapes are investigated. A review and expansion of the major points of each quarter's work is carried on to round out the student's course. A final project of the student's choice which will incorporate theory with practice and relate welding to his major field is made at this time.

In order to receive his Bachelor of Science degree, the student must also write a thesis. Welding holds its share of interesting problems to be explored. For example, a recent paper submitted to the department for approval was entitled "Electrical Welding in Aircraft." This paper dealt with the application of inert-gas shielded arc welding, resistance weld-ing, metallic arc welding and atomic-hydrogen arc welding.

The use of field trips for all majors in order to bring them into close contact with industrial plants is used. This is an additional means of familiarizing students with the activities of industry. Trips through steel mills, foundries, steel fabrication plants and others do much to illustrate the route from the drafting board to the finished product. The use of industrial films also adds to the student's information in the various welding proc-esses and related subjects. Attendance at technical meetings such as those which the A.W.S. presents are stimulating and thought-provoking to young men training to enter the welding filed. Participation in these activities should be encouraged by all concerned.

Practical Experience

To give the student first-hand experience it is necessary to undertake a variety of fabrication and repair projects. In this manner all of the experience from cost estimating to job supervising and actual welding practice are gained. An example of a project recently completed was that of a baseball backstop built up from 4- and 6-in. pipe (Fig. 4). An advanced welding student was assigned as project engineer to make cost estimate, oversee the sub-assemblies and supervise the final as-sembly on the baseball field. Under the direction of the project engineer, six students carried out the welding and rigging necessary for the job. A special engineering project now under way is that of installing a submerged melt arc-welding head. Plans call for the head to operate in two ways: one where the work piece is mounted on a positioner and the head remains fixed; the other, where the head moves on its carriage and the work remains in a fixed position.

Of course, it must be understood that the welding section relies upon many other departments to provide the bulk of the student's instruction. For advanced welding work it is necessary to set up prerequisites in order that students gain a maximum of necessary information prior to enrolling in these courses. Drafting is essential because after the first year most of the work produced is in the form of the design of weldments. In the me-chanical engineering course, Strength of Materials, is required because without it no student could successfully undertake or understand the fundamentals of design problems. Courses in college mathe-matics are also required.

Under the heading of "Special Prob-lems" are given courses for those students who wish to go further into the various aspects of welding than they are permitted in the regularly scheduled program. Stu-dents are on their own to design a project with complete specifications and cost estimates. The job can then be made up if time and space in the shop permit. In this way the student at least has a complete set of plans and specifications with which to start his engineering career. An example of a project in the Special Problems course by an agricultural engi-neering major was the design and fabrica-tion of a special type of hay baling trailer to be used in the area. Ranchers nearby rely on the use of the pick-up baler ex-tensively. Much labor is involved in loading the scattered bales from the hill-side fields after the baler has passed. This particular trailer was designed to follow the hay baler and receive about fifteen bales before dumping at convenient loading spots. It can be readily seen that by using this device the rancher's efficiency could be greatly increased. It is this sort of problem-solving on the job that we like to encourage and develop in our students.

If schools are to do a good job of training for industry they must by all means keep up with the developments and practices in industry. A training program must be realistic to be effective. The future plans of this welding department call for new equipment and course expansion. New equipment to be purchased will include an automatic shape cutting machine to demonstrate the principles of mass pro-duction shape cutting with two or more torches. In our experimental and testing laboratory, plans call for the installation of a controlled temperature annealing furnace to demonstrate the principles of preheating and annealing in direct rela-tion to weldments. Additional chemical and physical testing equipment is also planned for the near future. For ex-ample, the apparatus for the direct combustion method of determining the carbon content of steel is to be set up in the test laboratory. In many cases the difficulty encountered in poor welds is traceable to the high carbon content in the base metal rather than in a fault of the welding process. Expansion of courses will match new developments in the field as they arise. Our textbook might well be the current WELDING JOURNAL for this.

It is the goal of California State Poly-technic College to present welding as a related college engineering course geared to industry. With an adequately equipped shop, an inclusive course of instruction, and a practical project system, a college can present a well-rounded pro-gram which will enable its students to enter industry with an up-to-date knowl-edge of the application of welding.

Repair of Welded Ships*

By L. F. Bledsoe†

Due to the atmosphere of urgency and conditions of adversity which are usually present, there is a tendency to neglect or disregard the problems encountered in the structural repair of welded ships. This attitude, fostered by a lack of recognition of the potential dangers involved, often leads to structural failure in the repair area.

The fundamental aim of all ship repair is to do whatever work may be necessary to enable the vessel to fulfill its design functions and to perform this work in such a manner that it does not result in structural failures, either during the repair operations or subsequently during the service life of the vessel.

Experience has proved that proper consideration of design, sequence, procedure, workmanship, inspection and postweld treatment can result in workable practices which, if properly carried out, will reduce considerably the probability of fracture.

IN RECENT years, spurred on by the many structural failures of welded ships, much thought, research and publicity have been devoted to the engineering problems involved in the construction of such vessels. Attention has been focussed on the welding engineering factors of design, sequence, procedure and workmanship and it has been concluded by authoritative bodies that each plays an important part in the completion, without structural failure, of a welded vessel.[1] Moreover, it has been concluded that poor design and faulty workmanship constitute liabilities throughout the life of the vessel.[1] In spite of all the effort that has been aimed at the elimination of structural failures, welded ship construction is still fraught with uncertainty, and many important questions remain to be answered.

The repair of welded ships is also of an uncertain nature. It contains all the clouded issues and unknown factors which are present in new construction along with a few others, peculiar to repair, which lend an added emphasis to the uncertainty of the operation. There is ample evidence, in the form of a greatly increased fracture frequency rate during repair, to lead to the conclusion that repair is more critical than new construction. The problem of preventing structural failures, which is of such grave concern to the shipbuilding industry, is no less important, but more difficult of solution during the structural repair of welded ships.

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† Newport News Shipbuilding and Dry Dock Co., Newport News, Va.

It is the purpose of this paper to discuss the difficulties encountered in welded ship repair and to present certain practices which have been adopted in an effort to eliminate structural failures resulting from repair work.

Two conditions underlie most of the difficulties encountered in ship repair: First, the atmosphere of urgency which generally pervades the job and, second, the inherent nature of repair which necessitates burning and welding on an already completed hull girder. The first condition, fostered by the owner's desire to get his vessel back into service as quickly as possible, results in insufficient planning, congested work areas, improper preparation before welding, poor supervision and cursory inspection. Needless to say, faulty workmanship is an inevitable result. Fortunately, these factors are recognized and can be anticipated. The quality of the resulting welds will be varied, within limits, in direct proportion to the efforts expended by the personnel involved. Such is not the case with the second condition.

Although volumes of data have been complied concerning the residual and reaction stresses resulting from welding under certain conditions, it is still impossible to predict, quantitatively the effects of welding on any structure as large and complex as a completed ship. The forces which evidence themselves in the form of distortion in less complex and more flexible structures, and even in ships under construction, usually do not become apparent during repair work until fracture occurs.

The welding engineer is confronted with the problem of devising ways and means of preventing fracture although the mechanics of fracture are not fully understood, and there is nothing except experience to dictate the extremes to which the preventive measures should be carried. Nevertheless, collision, grounding, storm and the necessity for alteration or conversion take no heed of ignorance, and, until such time as welding is a more exact science, it is necessary to proceed cautiously, utilizing whatever means are at hand to accomplish repair without structural failure.

Experience over a period of years has resulted in the development of certain practices which contribute materially toward successful ship repair. Such practices are designed primarily to achieve sound welds and tolerable stress conditions and usually take the form of refinements of design, welding procedure and welding sequence. There are other means, not yet fully appreciated, which point the way to practices which may be adopted in the future. These current practices and possible future practices are presented here for what they may be worth to yards engaged in ship repair work.

Design

Although many features are being incorporated in the design of new vessels for the purpose of avoiding stress concentrations, "hard-spots," abrupt changes in section, excessive amounts of welding and too great proximity of welds, unfortunately these features are very apt to be

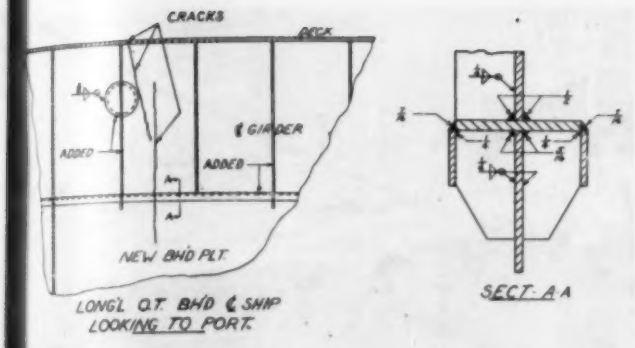

Fig. 1—Structural Failure Caused by Welding

overlooked in repair work. Then, too, there is a tendency to design welded alterations or additions without due regard to the stresses created by extensive welding on structural components which are already wholly attached to surrounding structure and are not free to move. By way of illustration of the above, Fig. 1 shows a specific instance on a T-2 tanker in which the welding attendant to the addition of stiffeners and patch plates to the upper center-line girder and the extension of the girder to create a center-line bulkhead resulted in complete fracture of the girder and partial fracture of the deck and new bulkhead plating.

Good practice dictates that attachment welds to existing structure be kept to an absolute minimum. Continuous welds should be avoided wherever possible. When it is necessary to make extensive structural additions, provisions should be made for releasing the members to be welded from the surrounding structure during welding operations. If this procedure is impossible or impractical, which is so frequently the case, riveting should be adopted as the method of attachment. Riveting is a valuable adjunct to welding and should not be overlooked as a possible solution to difficult design problems.

The frequency with which fracture occurs during the closing of openings by means of welded patch plates has led to the adoption of two design features which tend to alleviate the dangerously high stress condition attendant to the welding of such locked-up joints. Figure 2 illustrates these two devices. Item (*A*) depicts the use of a "dished" plate commonly employed as a flush patch in circular openings. The "dish," introduced into the patch plate before welding, affords sufficient flexibility in most cases to prevent fracture as a result of the welding operations. A $^{3}/_{16}$-in. dish is usually enough to achieve this and most of this is removed during the welding operation. Dishing is not considered necessary in patch plates over 15 in. in diameter. On the other hand, it is quite difficult to achieve in plates less than 6 in. in diameter, and for this reason it is not recommended that very small flush patches be employed. If it is necessary to use such small flush patches, a single V joint with a back-up ring should be utilized. It would be more desirable to enlarge the hole or to use a lap patch.

Item (*B*) depicts one corner of a rectangular flush patch the boundaries of which do not fall in way of original butts and seams. The rounded corner, having a minimum radius of 4 in., serves to eliminate the sharp intersection of highly stressed welds and is very beneficial in the prevention of fractures emanating from the corners of the patch.

Patch plates whose boundaries fall in way of original butts and seams are treated somewhat differently and will be discussed under the heading of "Welding Sequence."

Welding Procedure

The welding procedure generally employed in repair work differs little from normal ship welding procedures. Every effort is made to achieve sound welds, the joints being designed to facilitate the welding and chipping operations. A bead-on-bead sequence, in which the first bead is quickly followed by the next succeeding bead, is usually employed in the root, followed by stringer beads to complete the joint. The block system is not favored because of the necessity of chipping the ends of the blocks. Welds made from both sides are back-chipped to sound metal before welding the second side, and peening is employed in locked-up joints for all except the first and last beads. Preheat is used very generously and is believed to be the most important single feature of any procedure, particularly during the winter months.

The benefits of preheat, which have long been recognized in welded construction, are listed here for the purpose of discussion: First, it improves the arc action of the welding operation, affording the welder easy manipulation, which deposits a more smooth and sound first bead, as compared with welding on a cold plate. Second, it prevents the too severe cooling of the first welding beads, thereby avoiding the crack down the center of the bead which sometimes occurs when shrinkage stresses of too high an order are allowed to work on so small an amount of deposited weld metal. Third, the slower cooling rate afforded by the preheat is of decided metallurgical value in improving the ductility of the weld metal and the base material in the heat-affected zone. Fourth, it retains the tough and ductile condition of the steel throughout the cooling cycle by keeping its temperature above the transition point. Fifth, continuous application of preheat throughout the welding operations allows work stoppage to occur without subsequent cooling and stressing of an incompleted joint. To be most effective, preheat should be maintained throughout the cooling cycle in order to allow sufficient time for plastic deformation and "absorption of stress."

It will be noted that some of the benefits depend on the continuous application of the preheat. For this reason electric strip heaters, which furnish an even and easily controlled heat, are much preferred to the use of torches. These "heater-bars," usually of 750 or 1000 watt capacity, and operating on 220 v., a. c. or d. c., are capable of producing and maintaining plate temperatures of up to 150° F. under quite rigorous climatic conditions.

For ease of application the bare strip heaters are en-

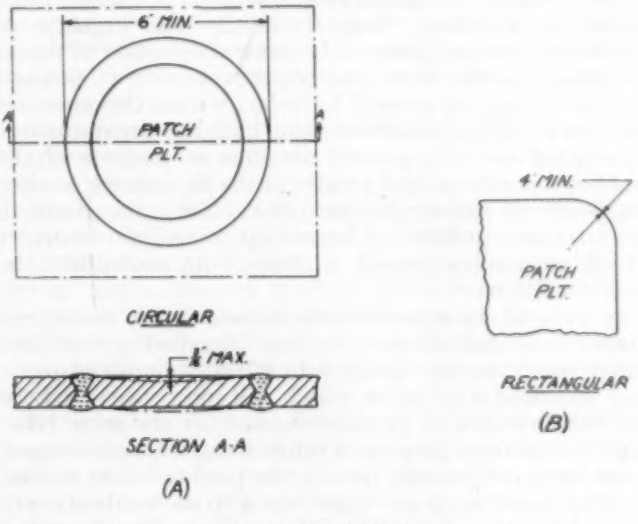

Fig. 2—Patch Plates

closed in a simple sheet metal case with appropriate electrical insulation for safety purposes and with glass wool insulation to serve the dual purpose of preventing heat loss through the case and directing the heat into the structure to which it is attached. Figure 3 shows the various components of a unit. The sheet metal cases may be easily attached to the structure to be heated by the use of metal clips which are tack-welded to the structure and extend over the flange of the case or by tack-welding the metal case directly to the structure. Usually these bars are connected in groups of two or three and wired to a common receptacle plug in order to simplify the required electrical connections and to reduce the number of electrical outlets necessary. Portable receptacle boxes are located in the immediate work area to eliminate the necessity for long extensions.

The accepted practice in applying these strip heaters is to parallel the joint to be welded with two lines of the units placed end to end, and about 6 in. to each side of the joint. Figure 4 shows these bars in use on a typical shell repair. These strip heaters, contrary to general opinion, interfere very little with normal production procedures and are surprisingly easy to apply to the average job. The insignificant added difficulties attendant to their use are far overshadowed by the benefits derived.

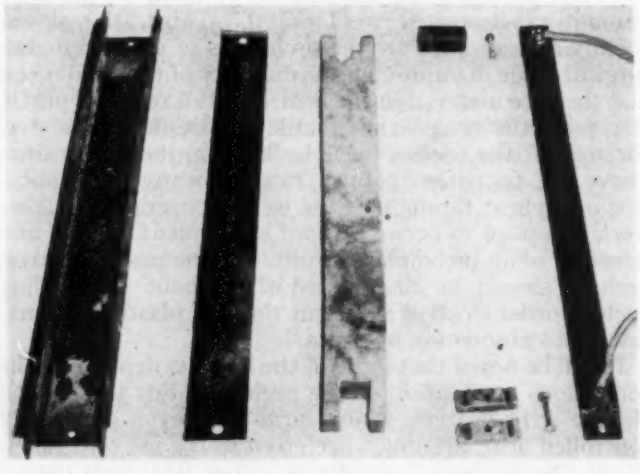

Fig. 3—Components of an Electrical Strip Heater Unit

Welding Sequence

Unfortunately, due to production difficulties, it is not always possible to adhere closely to the established principles of sequence. Too frequently the urgency of schedules does not allow a desirable disposition of repair personnel on the vessel and requires welding to proceed simultaneously in several locations within the same repair area. These conditions preclude any great amount of control over the general direction of progress of the welding operations and results in the occurrence of closing joints at undesirable locations. They also result in an increased number of locked-up joints, too many of which are always present in repair work even under the best conditions.

In view of the above conditions and in the absence of drastic remedial changes in over-all repair procedures, which would be very difficult to affect, it becomes necessary to adopt a sequence which will most nearly satisfy the requirements of production, and, at the same time, fulfill its primary purpose of minimizing reaction stresses. Time does not usually permit the production of a carefully prepared sequence, tailor-made to the needs of every individual job. Therefore, it is necessary for the supervisory personnel to formulate and carry out the required sequence for each job. For this reason, any basic sequence must be simple and flexible in order to facilitate its repetitive application to the variety of conditions encountered.

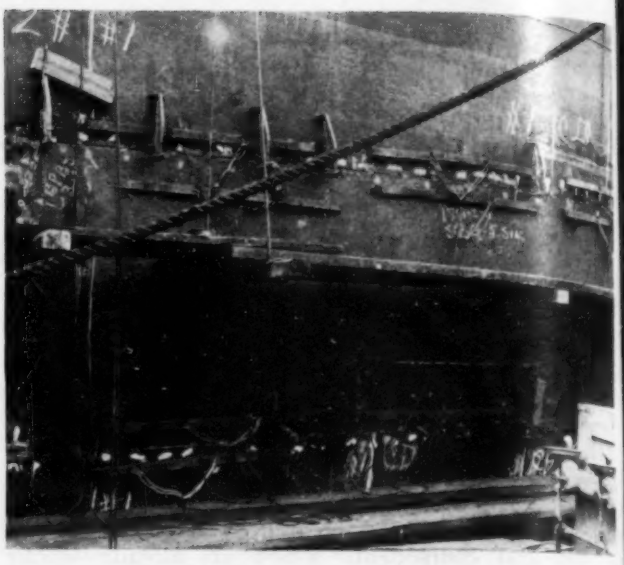

Fig. 4—Electrical Strip Heaters in Place on a Typical Shell Repair

Figure 5 depicts a typical welding sequence for the renewal of a single plate in any expanse of welded plating such as shell, deck or bulkhead. Crosses, x, indicate termination points for increments of fore-and-aft welding. Small circles, ○, indicate termination points for the increments of athwartship welding. Note that the sequence numbers are so arranged that longitudinal seam welds are stopped short of transverse butts and are not continued across the butts until after the butts have been welded. Note, also, that attachment welds connecting the framing or stiffening members (bulkheads, web frames, longitudinals, etc.) to the plating are stopped short of unwelded butts and seams and are not carried across such joints until after they have been welded.

Although the plate is not entirely free to move at any time during the welding operations, because of fitters tacks, sufficient elastic and plastic flexibility is afforded during the welding of the butts and seams by leaving the plating unattached from the framing members for approximately 12 in. each side of the joint. This is accomplished by cutting back the attachment welds around the perifery of the opening and by stopping short the attachment welds on the patch plate. A slight amount of added flexibility is obtained by splitting back the old seam welds for about 12 in. at all four corners of the opening. Most of the attachment welding to the patch plate is done before the welding of the final butt and seam in order to reduce the "drum-heading" which

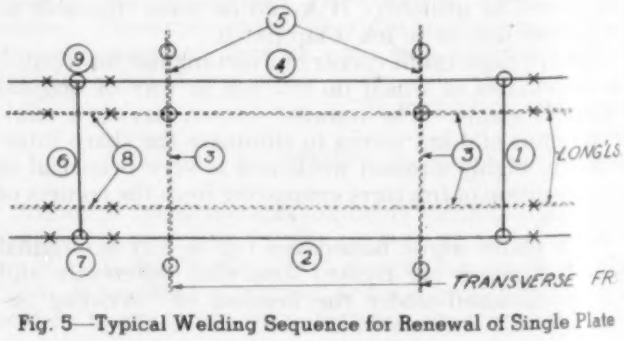

Fig. 5—Typical Welding Sequence for Renewal of Single Plate

would occur if all the attachment welds were made as a last step.

The principles of the above sequence can be applied successively to any number of adjoining plates or plating subassemblies to cover any area. The established practice of progressing forward and aft from amidship and outward from the center-line of the vessel is followed wherever possible.

In welding structure other than plating, the sequence follows the established principles of progressing away from parts of the structure which are already fixed in position toward parts which are more free to move and completing as much welding as possible on each unit before tying it to the fixed structure.

Inspection

An examination of almost any ship failure will disclose the presence of a mechanical notch at the origin of the fracture.[1] Too often this notch is a defect in the deposited weld metal. In all fairness to the welders, it should be stated that it is not believed to be within their power to exclude all of these defects, particularly under the conditions prevailing during most ship repair jobs. Regardless of the cause of the defects, however, they are recognized as being very important contributing factors in the structural failure of welded ships[1] and therefore, should be eliminated if possible. Inspection offers the only positive means of accomplishing this result.

Except for the occasional use of Magnaflux and, in very rare instances, the use of radiography, inspection is confined to visual examinations at various stages of completion of the welding operations. It is evident from the inspection of radiographs of completed welds and the examination of ship fractures that visual inspection is not sufficient. Radiography offers the most obvious means by which the quality of ship welds may be improved.

X-ray units which are comparatively rugged, compact, easily adapted to portability and simple to operate are now standard tools of industry. A few such units are now in use in Shipyards on certain new construction jobs for the Navy and are proving their worth in achieving sound welds. It is regrettable that the shipbuilding and repair industry has not seen fit to avail itself of the full benefits of this tool.

Controlled Low-Temperature Stress Relief

Controlled low-temperature stress relief[2] has been applied to many T-2 type tankers in very recent years as a precautionary measure against ship fracture. This treatment is applied to all welded butts and seams in the shell and deck within the tank area with the exceptions of the vertical butts in the side shell and the stringer-shear connections and is usually performed in conjunction with the application of eight crack arresting, riveted longitudinal seam straps. Any subsequent repairs within the stress-relieved portions of these vessels are also given the same treatment.

It is the aim of this process to effectively reduce the high order stresses within the zone of the weld and thereby slacken the taut tension bends along the welded joints, allowing more of the surrounding structure to accept a share of applied service loads. There are still two schools of thought as to the efficacy of the process in achieving a safer vessel, and the basic question as to whether or not the process has merit has not been answered to the satisfaction of all concerned. However, it is hoped that the answer will be obtained in the not-to-distant future through research or through compiled

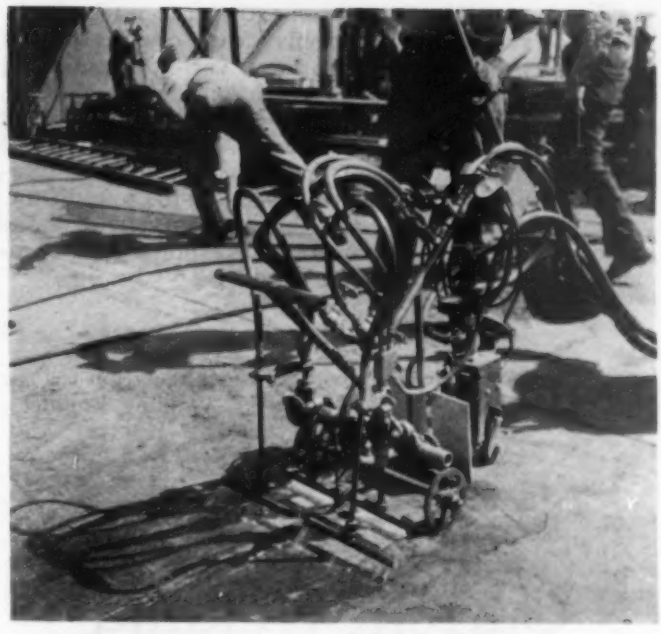

Fig. 6—Application of Controlled Low-Temperature Stress Relief to the Deck of a Tanker

data on the fleets of tankers which have been treated within the last few years. Until such time as conclusive evidence is forthcoming, it will be well to view this treatment with an open mind.

It is possible that this convenient and cheaply applied process may offer to the Shipbuilding and Repair Industries a means of substantially lowering the fracture frequence rate of welded ships through the treatment of a stress condition which is, as yet, impossible to avoid. Figure 6 shows the application of this process to the deck of a T-2 type tanker.

Conclusion

It is interesting, and very gratifying, to note that, in spite of the difficulties sometimes experienced during the repair of welded ships, no instance is known in which failure has occurred as a result of the repair after the vessel was returned to service. It is not known whether this may be attributed to the goodness of the repairs or the Author's lack of authentic and comprehensive information.

However, there is no lack of evidence concerning the effectiveness of the repair methods, as discussed above, in preventing fractures during repair operations. This has been vividly illustrated on several occasions when, through oversight or negligence, some cardinal precaution was omitted.

Summed up briefly, these precautions consist of: (1) Proper consideration, during the design of alterations and repairs, for the effect of welding on the structural parts which are already fixed in position; (2) the use of dished plates for closing circular openings, and rounded corners on small rectangular patches; (3) the generous and continued application of preheat throughout the welding operations; (4) an adequate welding sequence; (5) cutting back attachment welds and splitting old seams in way of locked-up joints and (6) an adequate inspection setup.

It is believed that radiography will play a role of increasing importance in shipbuilding and repair in the future, and that controlled low-temperature stress relief may prove to be effective in combating the structural failure of welded ships.

The writer does not presume that the methods described in this paper are the only means, or even the best means, at the disposal of ship repair yards for combating ship fractures during repair operations. It is possible, and very probable, that other practices are being utilized by other organizations to accomplish the same results. It is believed that greater dissemination of such information would be of invaluable assistance to the Industry.

Any opinions expressed in this paper are those of the writer and are not to be construed as expressions of Company policy.

Acknowledgments

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Spot-Welding Schedules for Nickel and Nickel Alloys*

By Frank G. Harkins†

The report discusses the development of spot-welding schedules for nickel and nickel alloys. Experiments in welding nickel and nickel alloys of 0.005 in. thickness are described. Particular attention is given material preparation and chemical cleaning procedures. Schedules for welding dissimilar metal thicknesses such as 0.005 to 0.040 in. are developed. Various methods of achieving "heat balance" to insure proper nugget location are pointed out. The importance of electrode size and composition, pressure time, current, and mechanical considerations are investigated. Tentative schedules for adoption by the Resistance Welding Committee are submitted.

Introduction

IN ORDER to increase the general fund of knowledge of resistance welding processes and applications, Subcommittee V of the Resistance Welding Committee, has investigated the spot welding of dissimilar thicknesses of nickel and nickel alloys. The Committee's report for 1947 covered the welding of these materials in extremely thin gages. This information is cataloged in Solar Aircraft Co. Research Division Report No. 691. Copies of this report have been filed with the AMERICAN WELDING SOCIETY.

The current year's program covered the development of spot-welding schedules for nickel, Monel and Inconel in thicknesses of 0.125, 0.094, 0.063, 0.031, 0.021, 0.015, 0.010 and 0.005 in all combinations. The work was performed by the author. A. L. Bennett, Research Technician and H. L. Winter, Production Resistance Welding Supervisor, acted as observers and have attested to the accuracy of the data which is to be presented.

Conclusions

The conclusions which may be drawn from the experimental work are:

1. The major problem in spot welding dissimilar thicknesses of these alloys appears to be the attainment of proper nugget location. This phenomenon is more pronounced in Inconel than in nickel and Monel.
2. By varying electrode size and composition, vastly different thicknesses of material such as 0.005–0.125 in. may successfully be spot welded.
3. The use of the "twist test" provides an excellent shop criterion for adequate weld penetration in the thinner material.
4. Minimum weld spacing data as listed in "Recommended Practices for Resistance Welding" appear to be on the low side. Wider weld spacing is indicated.
5. Monel and nickel are less susceptible to "poor heat balance" than are Inconel and stainless steel. If the ratio of sheet thickness in Inconel is greater than 2 to 1, corrective measures must be taken to insure proper nugget location. In nickel or Monel, if the ratio is greater than 3 to 1, corrective measures must be taken.
6. The macro etch test is recommended as a production control procedure when welding these thin alloys, since "stick" welds of remarkably high strength are readily obtainable. The use of the macro etch test will disclose this undesirable condition.

Material

The material which was used in establishing the schedules was furnished by the International Nickel Co. Typical chemical analysis of these materials were as shown in Table 1. Typical mechanical properties were as shown in Table 2.

Equipment

Tests were performed on 100-kva. and 150-kva., 400-v., 60-cycle welding machines. Fully synchronous control equipment with N.E.M.A. 9-B sequence panels were employed. Operation of the equipment was thoroughly checked before testing was begun. Service work on the welding machines included:

1. Investigation of the wave form and phase shift apparatus by means of a Laboratory Model Cathode-Ray Oscilloscope. Function and accuracy of the timing circuits were checked by means of a cycle-recording device. The heat control dial of the machine was calibrated directly into amperes so that the desired current

Table 1*

	Nickel	Monel	Inconel
Heat No.	765-A	M-2356	NX-5385
Carbon	0.06	0.12	0.09
Manganese	0.24	0.89	0.23
Iron	0.08	1.69	7.33
Sulphur	0.005	0.005	0.007
Silicon	0.05	0.18	0.14
Copper	0.03	30.72	0.12
Nickel	99.51	66.37	77.49
Chromium	....	....	14.59

* Data furnished by the International Nickel Co.

* Scheduled for Twenty-Ninth Annual Meeting, A.W.S., Philadelphia, Pa. Oct. 25–29, 1948.

† Solar Aircraft Co., San Diego 12, Calif.

Table 2*

Specimen, Thickness, In.	Breaking Load, Lb.	Tensile Strength, Psi.	0.2% Yield Strength, Psi.	% Elongation per 2 In.	Average Hardness, $VHN_1 - p$
		Monel			
0.002	53	52,600	22,400	7.8	62.4†
0.002	52	52,000	22,300	9.3	...
0.005	164	65,300	22,400	19.1	83.4
0.005	158	63,200	21,600	18.8	...
0.010	370	73,700	27,200	45.3	111
0.010	375	73,400	27,300	42.2	...
0.015	520	69,050	25,800	42.2	112
0.015	536	70,600	23,500	41.4	...
		Nickel			
0.002	41.5	39,300	11,400	6.3	38.6†
0.002	40.5	38,500	11,200	9.3	...
0.005	125	49,900	11,600	18.3	57.2†
0.005	123	49,200	12,400	19.5	...
0.010	267	53,100	10,800	18.0	71.3
0.010	268	53,400	11,900	20.3	...
0.015	407	54,700	12,200	31.1	91.3
0.015	411	55,500	12,600	35.4	...
		Inconel			
0.002	81.8	81,200	38,700	13.3	89.5†
0.002	80.3	80,100	38,900	12.5	...
0.005	273	109,000	40,300	27.2	143
0.005	279	111,000	40,900	28.2	...
0.010	575	114,100	51,500	30.5	166
0.010	563	108,200	50,000	32.0	...
0.015	715	94,100	38,600	35.9	152
0.015	750	98,600	35,500	38.3	...

* Data furnished by the International Nickel Co.
† Subject to question because of need to stack the samples. Impressions cupped.

could be approximated. A pointer stop ammeter with a suitable current coil was used for this purpose. This apparatus was left in the circuit. Current was measured on each material combination.

2. A Brinell microscope was employed for checking nugget size, penetration and weld spacing.

3. Electrode force measurements were made on each gage combination by means of a pressure meter.

4. Tension-shear testing was done in a 20,000-lb. Southwark machine.

5. Electrode holder: Because of the difficulties involved in maintaining consistent low-pressure on a spot-weld machine which employs a 6-in. diam. air cylinder, it was decided to allow the piston to bottom on each stroke of the head. In welding the very thin foils, a special spring-loaded electrode holder was procured. Electrode force is calibrated directly in pounds on one end of the holder. The accuracy of this tool was checked against the pressure meter.

Experimental Work

Material Preparation

Mechanical cleaning was accomplished by means of No. 400 emery paper. Specimens were polished until a relatively dull surface appeared. For testing purposes this is probably the most convenient method of material preparation. However, several chemical cleaning processes were applied with excellent results. Since it was felt that the evaluation of the several chemical cleaners were beyond the scope of the investigation, no attempt was made to measure the surface resistance of the specimens after they had been chemically treated. Best visual conditions existed after the specimens had been processed for 5 min. in molten caustic soda, containing sodium hydride. However, a few seconds immersion in dilute nitric acid gave good results on the nickel.

A mixture of 10% nitric acid, plus 1–2% hydrofluoric acid, remainder water, was effective on the Inconel and Monel specimens. There were no observable difference, due to cleaning methods, in the weldability of the materials. Welds in the materials which had been cleaned (either chemically or mechanically) showed much better tension-shear consistency than those which were made in the "as-received" condition.

Electrodes

The importance of electrode composition, size and shape in welding nickel and nickel alloy materials in dissimilar thicknesses cannot be over-emphasized. The

Fig. 1—Special Electrode Holder Used for Maintaining Consistent Electrode Force in Welding Extremely Thin Materials, Such as 0.005 In.

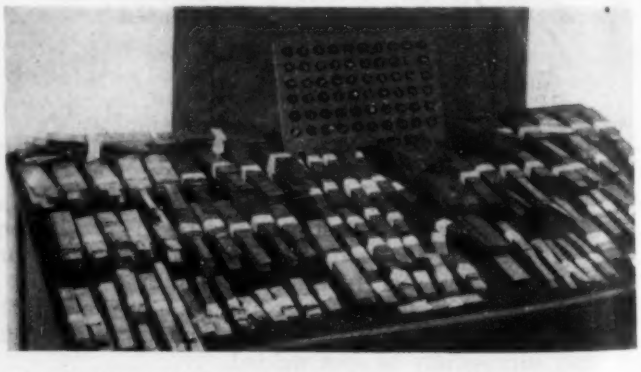


Fig. 2—General View of Tension-Shear and Mounted Specimens Illustrating the Scope of the Project. The Experiments Involved Over 2000 Welds and Over 100 Mounted Specimens

electrode materials which were employed in the investigation were molybdenum, copper and copper alloys, such as R.W.M.A. Classes I, II, III and XI.

Dome-shaped electrodes with 3 in. radius were employed exclusively. For materials of equal thickness, Class II, Group A electrodes will produce satisfactory results with a minimum of maintenance. On thin gages of nickel (0.015 or less), Class I or copper electrodes are recommended, since the tendency of these electrodes to alloy with the work is minimized.

It was found to be not practical to use electrodes of smaller than $^5/_{32}$ in. diam. This dimension was established because it appeared to produce welds which were of good metallurgical characteristics. The relatively large electrode causes the nuggets to appear somewhat abnormal in shape since the ratio of the major axis to the minor axis of the ellipse is of the nature of 5 to 1 instead of the conventional $3^1/_2$ to 1. Little can be done to cause the nugget to be more evenly proportioned without reducing electrode diameter to a point where indentation and maintenance would become excessive. If the standard electrode size formula (2T + $^1/_{10}$ in.) were applied, it would give an electrode diameter of 0.110 in. It is highly doubtful that this electrode would be serviceable for many spot welds. Since, as may be expected, the welding of these thin materials requires the most accurate control of pressure, current, surface condition and time, even slight mushrooming of the electrodes could be disastrous. For this reason, it is highly recommended that the relatively large $^5/_{32}$ in. diam. electrode be employed.

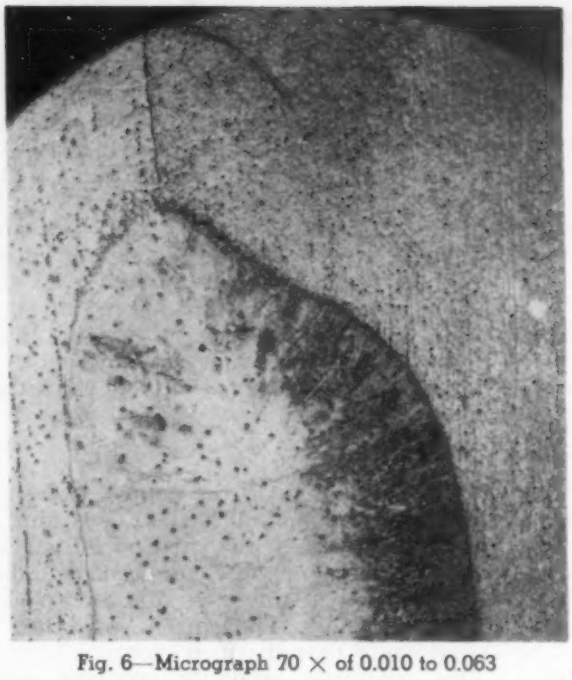


Fig. 6—Micrograph 70 × of 0.010 to 0.063

Notice penetration into thinner material and peculiar nugget shape.

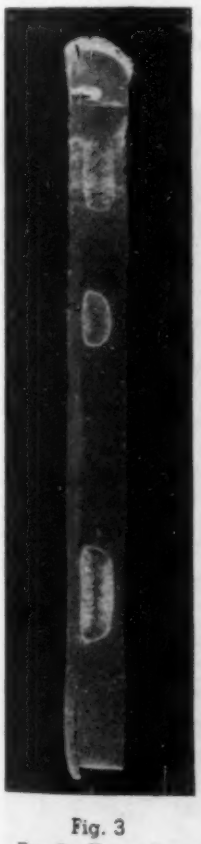


Fig. 3

Fig. 4

Fig. 5

Fig. 3—Typical macrograph illustrating the effect of weld spacing on nugget size. You will note that the values of pressure, time and current were approximately correct (as judged from nugget structure), yet penetration in thin material is totally lacking. This weld was made by using 6 cycles, 5400 amp. at 400 lb. pressure with $^3/_{16}$-in. electrodes of Class 2 alloy. (Material—Inconel 0.010 to 0.063.)

Fig. 4—Improvement in nugget location accomplished by using electrode size called out in table. This weld was made using 6 cycles, 5200 amp. at 400 lb. electrode force with $^5/_{32}$-in. diam. electrode against 0.015 sheet and $^5/_{16}$-in. diam. electrode against 0.063 sheet. (Material—Inconel 0.010 to 0.063.)

Fig. 5—Adequate penetration into 0.010-in. sheet was obtained by using 400 lb. force with $^5/_{32}$-in. diam. molybdenum-tipped electrode, 8 cycles with 5500 amp. (Material—Inconel 0.010 to 0.063.)

Pressure

Pressure adjustment on thin materials appears to be very critical, if "stick" welds are to be avoided. The previously mentioned alloying of the electrode with the work can be largely alleviated through the use of low electrode pressure. In many of the experiments, on extremely thin materials, perfect welds between each electrode and the work were produced with no sign of a bond between the faying surfaces.

Electrode pressure has a pronounced effect on the welding current in nickel fabrication. With increasing pressure, extremely high welding currents will be required. For example, in welding 0.015–0.015 nickel at 700 lb. electrode force, currents of the nature of 30,000 amp. were required. When using the recommended 250 lb., the welding current was 12,300 amp.

Timing

It is generally considered to be good commercial practice to use relatively long weld time. Proper timing is conditioned by material thickness. Weld time for pure nickel will necessarily be short, because of considerations to be discussed later. There appears to be a direct correlation between the optimum weld time and the electrical resistance of the material. Since there is a limit to the degree to which the surface resistance of the material can be controlled, the importance of the R in the $H = I^2 RTK$ formula may be minimized by using greater T. The I of the formula cannot be permitted to become excessively large, because sparking at the electrode will become significant. Hundreds of tension-shear tests have indicated that welds made with relatively long weld time have greater tension-shear strength consistency than short-time welds (not necessarily greater tension-shear strength). It must be recognized, however, that in welding extremely thin gages of these materials, that another variable is introduced. This takes the form of a time-temperature consideration.

It is obvious that the time required for the welding heat to reach the surface of the thin material will be considerably shorter than that required to reach the surface in heavier gages. Further, the heat conductivity which can be directly correlated to the electrical conductivity and inversely correlated to the electrical resistance of the material, of nickel is much greater than that of Inconel or Monel. This characteristic places considerable restriction on the desirability of long weld times when welding pure nickel. It has been found in spot welding this material, that short weld times are absolutely essential if electrode pickup, sticking and keying are to be avoided. Possibly the rule in welding nickel would be to use as long a weld time, up to 20 cycles for heavier gages, as can be employed without sticking or electrode pickup.

Current

The "per cent heat" dial on the control equipment permitted current variation of 2000–32,000 amp. A wide range of current values was tried on all gages of all materials. After the pressure and time had been established, the current setting was adjusted so as to cause expulsion of metal. The current was then reduced to a point below that at which expulsion of metal occurred. This technique generally produced sound welds, although in the case of the "A" nickel, it had to be reversed because of the tendency of the material to stick to the electrode. Current settings in "A" nickel were established by starting at a low current and increasing current in small increments until a sound weld was obtained. This approach saved considerable electrode machining time.

Table 3

Indentation per sheet

Thickness	Nickel	Monel	Inconel
0.002	0.0002	0.0002	0.0002
0.005	0.0005	0.0005	0.0004
0.010	0.0005	0.0015	0.0007
0.015	0.001	0.002	0.002

Indentation

Maximum allowable indentation, according to AAF Specification, is 20% of the total thickness being welded, for structures which are not air foils. In dissimilar thickness welding, as will be seen from the macrographs, most of the indentation occurs on the thinner piece. This is understandable, in view of the fact that the electrode which contacts the thin sheet may have only one-tenth of the area of that contacting the thick sheet; so that the unit pressure on the thin sheet would be ten times greater than on the thick sheet. This condition is aggravated when a low conductivity electrode is used against a thin sheet—in the interest of obtaining heat balance—since more heat will be generated at the point of contact, causing a reduction in the mechanical strength of the thinner material. Table 3 lists the degree of indentation for the thin gage material.

Fig. 7

Fig. 8

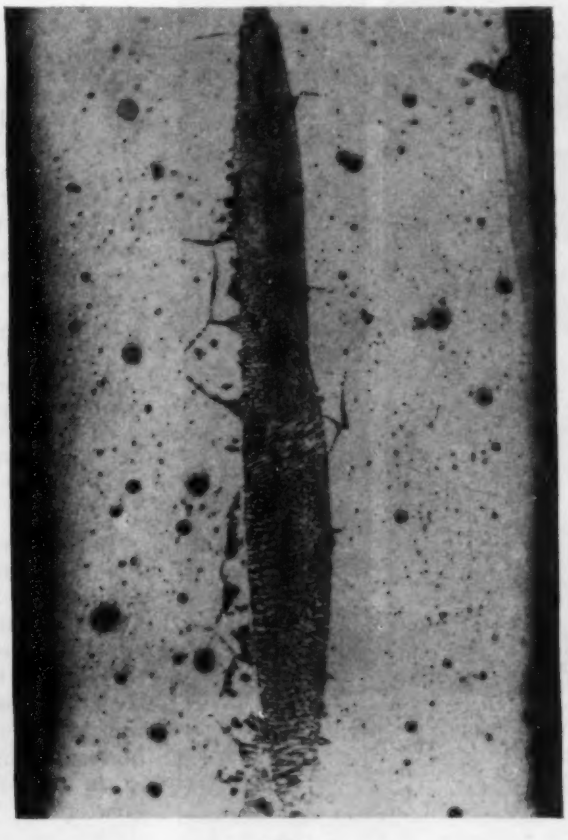


Fig. 9

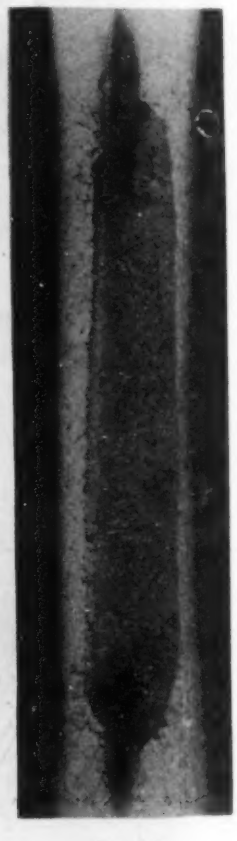


Fig. 10

Fig. 7—Macro 0.021–0.063, $^{3}/_{16}$-in., Class 2 electrodes, top and bottom. No penetration in 0.021 material, indicating that 3 to 1 material thickness ratio in Inconel cannot be handled with equal size electrodes. This weld was made using 12 cycles, 5600 amp. at 400 lb. pressure.

Fig. 8—Macro 0.021–0.063, $^{3}/_{16}$-in. molybdenum electrode: top, $^{5}/_{16}$-in., Class 2 electrode; bottom, 400 lb. pressure, 12 cycles, 5300 amp.

Fig. 9—Spot weld in 0.010 "A" nickel. 120 ×.

Fig. 10—Spot weld in 0.010 Monel. 50 ×.

Minimum Contacting Overlap

The minimum contacting overlap is the smallest value which, when using the schedules of Table 4, will prevent expulsion of metal. It is generally recognized that "edge" welds usually show subnormal tension-shear values. It is therefore necessary to establish minimum edge distances. Edge distance is determined by the area of the fused zone, which in turn is a function of the electrode diameter. Since, in welding thin materials, there is a lower limit to electrode diameter beyond which electrode maintenance cost would become prohibitive, it appears that the minimum contacting overlap which will avoid "edge" welding with its attendant expulsion of metal and loss of tension-shear strength, is 1/4 in. (The minimum practical electrode diameter has been established at 5/32 in.).

Diameter of Fused Zone

As previously noted, the diameter of the fused zone is directly related to the electrode diameter. Values of the diameter of a nugget are listed in Tables 4, 5 & 6. The extremely high ratio of the major to the minor axis of the nugget is felt to be satisfactory in view of the considerations noted in the discussion of electrodes. The diameter of the fused zone for all specimens was measured by means of a 20-power Brinell microscope. This was taken at the faying surfaces. In widely dissimilar metal thickness combinations it is not necessarily the major axis of the nugget.

Minimum Weld Spacing

Data on minimum weld spacing on very thin materials is difficult to gather. This is because the nuggets are small, making it very difficult to locate them. After the nugget has been located, one can never be certain that the section has been taken at the exact center. For this reason, it is felt to be not practical to express this figure as a decimal, since it necessarily is an approximation. Many factors contribute to the optimum weld spacing data. Some of these are:

1. The diameter of the fused zone.
2. The electrical resistance and its corollary—the heat conductivity of the material.
3. The composition, size and shape of the electrodes.
4. The surface resistance of the material.

Quite naturally, with all of these variables, it becomes difficult to specify a weld spacing which will hold true for all gages, all combinations and all compositions of materials.

Based on these experiments, there is a strong indication that the data which is listed in the tables in the "Resistance Welding Manual" is on the low side. However, the schedules appear to be extremely accurate and will produce welds of superior quality so that a small reduction in nugget size due to the shunting effect of the preceding spot is felt to be not particularly detrimental. The data on weld spacing, which is listed in Tables 4, 5 & 6 was obtained in the following manner:

Table 4—Spot Welding Annealed Monel Sheet

Thickness, In.	Electrode Diameter, In. Top	Bottom	Electrode Force, Lb.	Weld Time, Cycles 60 per sec.	Weld Current, Amp.	Contact Overlap, In.	Weld Spacing, In.	Diameter Fused Zone, In.	Shear Strength, Lb.
0.005 to:									
0.005	5/32	5/32	220	2	5,000	1/4	1/4	0.10	70
0.010	5/32	5/32	220	2	6,100	1/4	1/4	0.10	76
0.015	5/32	5/32	220	2	7,000	1/4	5/16	0.10	94
0.021	5/32	1/4	220	3	7,200	1/4	3/8	0.10	108
0.031	5/32	1/4	250	4	7,400	1/4	3/8	0.11	118
0.063	5/32	5/8	250	4	8,000	1/4	7/16	0.11	112
0.094	5/32	5/8	250	4	8,600	1/4	1/2	0.11	110
0.125	5/32	5/8	250	4	8,700	1/4	1/2	0.11	108
0.010 to:									
0.010	5/32	5/32	270	2	7,200	1/4	1/4	0.12	180
0.015	5/32	5/32	280	2	8,600	1/4	5/16	0.12	196
0.021	5/32	5/32	280	3	8,200	1/4	5/16	0.13	214
0.031	5/32	5/32	300	4	8,800	1/4	3/8	0.13	236
0.063	5/32	5/16	300	4	9,200	1/4	7/16	0.13	238
0.094	5/32	5/8	325	4	9,900	1/4	1/2	0.14	268
0.125	5/32	5/8	325	4	9,900	1/4	1/2	0.14	276
0.015 to:									
0.015	3/16	3/16	300	2	8,600	1/4	5/16	0.13	310
0.021	3/16	3/16	300	6	8,200	1/4	3/8	0.13	368
0.031	3/16	3/16	325	6	9,300	1/4	3/8	0.13	376
0.063	3/16	5/8	325	6	9,400	1/4	7/16	0.14	436
0.093	3/16	5/8	325	8	9,500	1/4	1/2	0.14	448
0.125	3/16	5/8	325	8	9,500	1/4	1/2	0.14	456
0.021 to:									
0.021	3/16	3/16	300	12	6,200	5/16	7/16	0.13	560
0.031	3/16	3/16	325	12	6,800	5/16	7/16	0.13	578
0.063	3/16	3/16	325	12	7,200	5/16	1/2	0.14	624
0.093	3/16	5/8	325	12	7,700	3/8	9/16	0.14	660
0.125	3/16	5/8	325	12	8,200	3/8	9/16	0.14	692
0.031 to:									
0.031	3/16	3/16	700	12	10,500	3/8	5/8	0.17	1056
0.063	3/16	1/4	750	12	11,200	1/2	11/16	0.18	1138
0.094	3/16	5/8	775	12	11,400	1/2	3/4	0.19	1296
0.125	3/16	5/8	775	12	11,800	1/2	3/4	0.19	1348
0.063 to:									
0.063	5/16	5/16	2700	12	15,300	3/8	1 1/8	0.31	2584
0.093	5/16	5/8	2700	12	15,900	5/8	1 3/16	0.31	2734
0.125	5/16	5/8	2700	12	16,200	5/8	1 1/4	0.32	2944
0.094 to:									
0.094	3/8	3/8	2760	20	22,600	3/4	1 1/4	0.37	4860
0.125	3/8	3/8	2760	20	25,000	3/4	1 1/4	0.38	5480
0 125 to:									
0.125	1/2	1/2	5000	30	30,000	7/8	1 5/8	0.47	7300

After a suitable welding schedule had been established, welds were made at various spacing in increments of 1/16 in. The "twist" test was used as an indication of the diameter of the fused zone. This was measured by means of the 20X Brinell microscope. When, from this examination, a nugget size equal to that of a single spot specimen was obtained, another sample weld was made. This weld was carefully sectioned and mounted. The nugget diameter was accurately measured with the microscope. In view of the limiting factors previously mentioned, the weld spacing data contained in the table is felt to be fairly accurate. Many of the accompanying macrographs illustrate the manner in which the weld spacing data were gathered.

Factors Affecting Nugget Location

Sufficient evidence has been obtained to indicate that the composition, size and shape of the electrodes are the major factors in attaining proper weld nugget location. In welding metals of dissimilar thickness, no precautions need be taken if the ratio of the thickness of the thinner piece to the thickness of the thicker piece is 2 to 1 or less for Inconel or 3 to 1 or less for Monel or nickel. In Inconel welding, if the ratio between thicknesses becomes 3 to 1, the use of the electrode diameters in Table 6 will usually result in adequate weld penetration in the thin sheet. When the ratio of metal thicknesses becomes greater than 3 to 1, it is necessary to use a low-conductivity electrode of the specified diameter against the thin sheet, while using a large diameter, high-conductivity electrode against the heavier piece. Weld nuggets under these conditions may assume a kidney shape; this peculiar nugget formation may be partly explained by the fact that the pressure in this area is higher in the center than at the edges, causing the electrical resistance to be lower and resulting in the generation of less heat. When the electrical resistance is lowered, the heat conductivity is raised, so that the electrode carries off the welding heat in this area by conduction at a greater rate than it does the heat at the periphery. It is reasonable to expect that the nuggets will have a decided dip at this area. Examination of the macro specimens shows this to be the case.

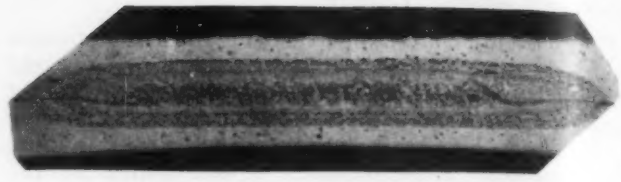


Fig. 11—Spot Weld in 0.010 Inconel. 50 ×

Tension-Shear Values

Tables 4, 5 and 6 list various tension-shear values which may be expected under the stipulated welding conditions. It must be pointed out that these values will vary slightly, either upward or downward, depending

Table 5—Spot Welding Annealed Nickel Sheet

Thickness, In.	Electrode Diam., In. Top	Bottom	Electrode Force, Lb.	Weld Time, 60 Cycles per Sec.	Weld Current, Amp.	Contact Overlap, In.	Weld Spacing, In.	Diameter Fused Zone, In.	Weld Strength, Lb.
0.005 to:									
0.005	5/32	5/32	100	3	7,100	1/4	3/8	0.10	40
0.010	5/32	5/32	100	3	7,400	1/4	7/16	0.10	45
0.015	5/32	5/32	110	3	7,500	1/4	7/16	0.10	48
0.021	5/32	5/32	110	3	7,800	1/4	1/2	0.10	58
0.031	5/32	3/16	110	3	8,000	1/4	1/2	0.10	63
0.063	5/32	3/16	115	3	8,100	1/4	5/8	0.10	65
0.093	5/32	3/16	115	3	8,150	1/4	5/8	0.10	65
0.125	5/32	3/16	115	3	8,200	1/4	5/8	0.10	68
0.010 to:									
0.010	3/16	3/16	130	3	11,800	1/4	3/8	0.12	170
0.015	5/32	3/16	130	3	11,900	1/4	3/8	0.12	180
0.021	5/32	3/16	130	3	12,000	1/4	7/16	0.12	190
0.031	5/32	3/16	130	3	12,200	1/4	7/16	0.12	202
0.063	5/32	3/16	140	3	12,300	1/4	1/2	0.12	234
0.094	5/32	3/16	140	3	12,300	1/4	5/8	0.12	240
0.125	5/32	3/16	150	3	12,500	1/4	5/8	0.12	260
0.015 to:									
0.015	3/16	3/16	250	3	12,300	1/4	7/16	0.12	225
0.021	3/16	3/16	250	3	12,500	1/4	1/2	0.13	310
0.031	3/16	3/16	250	3	12,600	1/4	1/2	0.13	350
0.063	3/16	1/4	260	3	12,800	1/4	9/16	0.13	372
0.094	3/16	5/8	260	3	13,000	1/4	5/8	0.13	380
0.125	3/16	5/8	260	3	13,100	1/4	5/8	0.13	390
0.021 to:									
0.021	5/32	5/32	370	4	7,800	5/16	9/16	0.12	440
0.031	5/32	5/32	370	4	8,200	5/16	5/8	0.12	462
0.063	5/32	5/32	370	4	8,600	5/16	5/8	0.12	496
0.094	5/32	5/8	380	4	8,800	5/16	11/16	0.12	535
0.125	5/32	5/8	380	4	9,000	5/16	3/4	0.13	566
0.031 to:									
0.031	3/16	3/16	900	4	15,400	3/8	7/8	0.18	950
0.063	3/16	3/16	900	4	15,200	3/8	7/8	0.17	866
0.094	3/16	3/16	900	6	13,500	3/8	1	0.18	1050
0.125	3/16	5/8	980	6	14,200	3/8	1	0.18	1160
0.063 to:									
0.063	1/4	1/4	1720	6	21,600	5/8	1 1/2	0.25	3000
0.094	1/4	1/4	1800	8	20,000	5/8	1 5/8	0.25	3188
0.125	1/4	1/4	1800	10	21,000	5/8	1 3/4	0.25	3316
0.094 to:									
0.094	5/16	5/16	2300	12	26,400	3/4	1 7/8	0.31	4500
0.125	5/16	5/16	2300	20	25,500	3/4	2	0.31	4720
0.125 to:									
0.125	3/8	3/8	3300	20	31,000	7/8	2 1/4	0.37	7000

upon all of the other factors in the schedules. Chemical composition, mechanical properties, surface resistance, size and shape, conductivity and make of electrodes are but a few of the factors which enter into the attainment of satisfactory tension-shear values. All of the schedules from 0.021 to 0.125, equal thickness materials, have been established by other experimenters. It is of interest to note, however, that in setting the dissimilar thickness schedules, the established tables were carefully checked. The results obtained were excellent in that the tension-shear tests were extremely close to those called out in the tables. (The materials which were used in our experiments were taken from the same heat as that used in establishing the original schedules.) It is felt that the macro etch test provides a more reliable index to weld quality than does tension-shear testing. Macro etch testing, plus "twist testing" precludes "stickwelds" which in these alloys may have remarkably high temporary strength. The macro etch test is probably the most effective means of checking weld quality. If this test shows a weld to be of good quality, the tension-shear test will demonstrate high strength. (Exception: Air hardening alloys such as 4130). If the tension-shear test shows high strength, it is not an infallible indication, especially in thin materials and materials of widely different gage, that a good quality weld has been produced. The tension-shear values shown in the tables are those which were obtained under the stipulated welding condi-

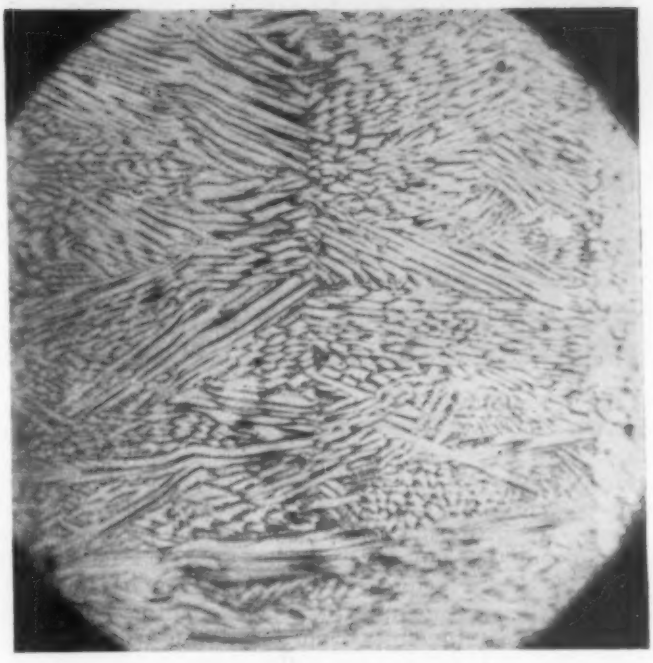


Fig. 12—Structure of Nugget 500 ×, 0.010 Inconel

Table 6—Spot Welding Annealed Inconel Sheet

Thickness In.	Electrode Diam., In. Top	Bottom	Electrode Force, Lb.	Weld Time, 60 Cycles per Sec.	Weld Current, Amp.	Contact Overlap, In.	Weld Spacing, In.	Diameter Fused Zone, In.	Shear Strength, Lb.
0.005 to:									
0.005	5/32	5/32	300	2	7,000	1/4	1/4	0.11	90
0.010	5/32	3/16	300	4	5,300	1/4	1/4	0.12	125
0.015	5/32*	3/16	300	4	5,500	1/4	1/4	0.12	135
0.021	5/32*	3/16	300	6	4,800	1/4	5/16	0.13	140
0.031	5/32*	3/16	325	6	5,400	1/4	5/16	0.13	150
0.062	5/32*	5/8	325	6	5,600	1/4	3/8	0.15	172
0.094	5/32*	5/8	325	6	5,800	1/4	3/8	0.16	184
0.125	5/32*	5/8	325	6	5,600	1/4	1/8	0.15	160
0.010 to:									
0.010	3/16	3/16	320	4	7,500	1/4	1/4	0.12	220
0.015	5/32*	3/16	320	4	5,500	1/4	1/4	0.13	270
0.021	5/32*	3/16	320	6	5,100	1/4	9/32	0.13	270
0.031	5/32*	3/16	350	6	5,600	1/4	9/32	0.14	360
0.063	5/32*	5/16	400	6	5,500	1/4	5/16	0.14	395
0.094	5/32*	5/8	400	6	5,800	1/4	3/8	0.15	440
0.125	5/32*	5/8	400	6	4,600	1/4	3/8	0.14	365
0.015 to:									
0.015	3/16	3/16	360	6	7,600	1/4	1/4	0.12	370
0.021	3/16	3/16	360	6	5,400	1/4	1/4	0.12	360
0.031	5/32*	3/16	400	8	4,600	1/4	9/32	0.13	460
0.063	5/32*	5/16	400	8	4,700	1/4	5/16	0.13	550
0.094	3/16*	5/8	400	10	4,700	1/4	11/32	0.16	670
0.125	3/16	5/8	400	12	4,600	1/4	3/8	0.16	700
0.021 to:									
0.021	5/32	5/32	300	12	4,000	5/16	7/16	0.12	680
0.031	5/32	3/16	350	12	4,100	5/16	7/16	0.12	670
0.063	3/16*	5/16	400	12	5,300	5/16	15/32	0.12	775
0.094	3/16*	5/8	500	12	5,900	5/16	1/2	0.15	828
0.125	3/16*	5/8	550	12	6,300	5/16	1/2	0.15	860
0.031 to:									
0.031	3/16	3/16	700	12	6,700	3/8	9/16	0.18	1150
0.063	3/16	5/16	700	12	7,100	3/8	5/8	0.18	1210
0.094	1/4*	5/8	700	12	8,300	3/8	11/16	0.20	1565
0.125	1/4*	5/8	750	12	8,500	3/8	3/4	0.20	1510
0.063 to:									
0.063	5/16	5/16	3070	12	12,000	5/8	1 1/8	0.31	3450
0.093	5/16	5/8	2450	16	12,000	5/8	1 3/16	0.31	3420
0.125	5/16	5/8	2600	20	12,000	5/8	1 1/4	0.32	3530
0.094 to:									
0.093	3/8	3/8	3870	20	15,000	3/4	1 3/16	0.37	5500
0.125	7/16	7/16	5100	30	20,000	3/4	1 1/4	0.40	5880
0.125 to:									
0.125	7/16	7/16	5270	30	20,100	7/8	1 5/16	0.44	8000

* Indicates molybdenum-tipped electrode.

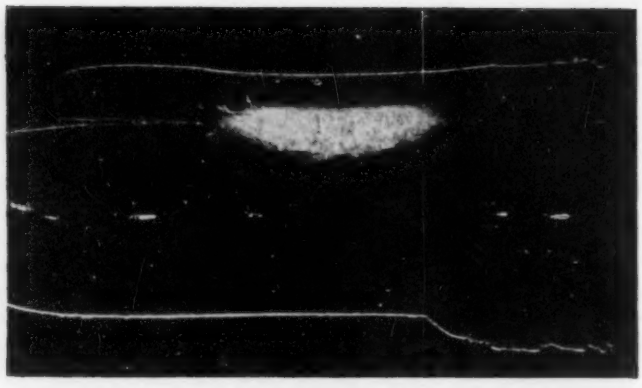


Fig. 13—Macro 4 ×, 0.021-0.125 Inconel. Adequate Penetration in Thin Material. Excellent Structure

tions. Higher or lower values may be obtained by varying the current, time, pressure and electrode size and shape. If, in setting a welding machine for production welding, the tension-shear test does not come up to the desired value, the nugget size may be enlarged by increasing the pressure and current—except for thin nickel. This will have the effect of increasing the effective electrode size.

Photography

Several photomacrographs illustrating the manner in which weld spacing data were gathered are presented. These were made from mounted specimens. The etchant used for the "A" nickel consisted of a solution of 10 cc. nitric acid plus 5 cc. acetic acid plus 5 cc. water used electrolytically. This etchant was selected because of the contrast effect which is so necessary for the microphotography of nickel. Ten per cent oxalic acid, used electrolytically, was employed on the Monel and Inconel specimens.

Because of the high purity of the nickel (99.51%), great difficulty was experienced in procuring suitable etched specimens. The theory of etching involves the preferential attack of some of the constituents by the etchant. Since the constituents of the "A" nickel consisted mainly of nickel, most etchants which were tried resulted only in a pitting attack on the parent material. However, when the welding conditions were such as to cause complete melting with its subsequent recrystallization, the nuggets were clearly visible after immersion in the nitric-acetic etchant. Because of the etching difficulties, most of the macrographs are of Inconel specimens.

The accompanying photographs are self-explanatory. The equipment used and the scope of the project are clearly indicated. As a matter of general interest, Fig. 14 was included. This is a micrograph of a rollweld in 0.001 A.I.S.I. Type 302 stainless steel. The end use of the product containing this weld was for tail-pipe insulation for jet engines. The fabrication involved joining strip, 12 in. wide, in order to form flat sheets 48 x 108 in. The use of Class 1 or copper electrodes is recommended on fabrications of this type, if excessive electrode sticking is to be avoided.

Summary

Nickel

1. Short weld times are indicated if pickup, sticking and mechanical keying are to be avoided.
2. Of the alloys tested, nickel is hardest to weld.

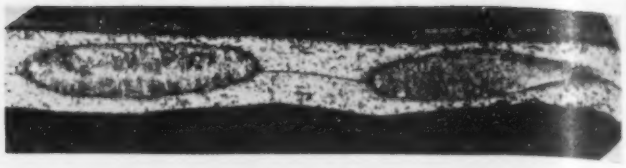


Fig. 14—Seam Weld in 0.001, Type 302, Stainless Steel. 70 ×

Stickwelds have very high strength—often as high or higher than sound welds—but extremely low fatigue life.

3. Due to the high electrical conductivity, and the necessity for short welding time, extremely heavy welding currents are required
4. Welds in annealed "A" nickel show remarkable fatigue life. The "twist test" on a properly executed weld, shows over 200° before complete failure.
5. Pressure adjustment on nickel foils is critical if excessive pickup, mechanical keying and alloying are to be avoided.

Monel

1. In no material combination was it necessary to vary electrode composition. All gages and combinations of Monel were welded with R.W.M.A. Class 2, Group A materials. When the ratio of thickness of thinner to thicker piece became greater than 3 to 1, change in electrode size was necessary to insure proper nugget location. The use of relatively long weld times has been demonstrated to be beneficial in Monel fabrications.
2. The macro etch test, in combination with the "twist test," will provide an adequate process control technique. The peel test has been found to be unreliable on gages of material of 0.015 and lower and on dissimilar metal thickness combinations. Peel testing is reliable, however, in equal thicknesses of 0.021 and higher.
3. Of the nickel alloys, Monel appears to be the easiest material to weld. Wide variations of time and current are permissible. A tension-shear test of a properly executed weld in Monel will generally demonstrate parent material strength. Many of the tension-shear specimens pull "double buttons," i.e., the material pulls out from each side.
4. Stick welds in Monel often show remarkably high strength. For this reason, macro etch testing is essential.

Inconel

1. Of the alloys tested, Inconel is most susceptible to poor "heat balance" characteristics.
2. Little difficulty with electrode pickup, sticking or keying will be experienced in welding Inconel.
3. Electrode force may be increased in order to prevent sparking when welding work-hardened materials
4. Because of the work-hardening characteristics the use of Class III electrodes is recommended if electrode maintenance is to be minimized.

Acknowledgments

In closing the author wishes to acknowledge the efforts of A. L. Bennett and H. L. Winter on weld testing; J. W. Welty on the metallurgical aspects of the program and S. P. Weston on the photography. All of these men are members of the Solar Research Staff. Appreciation is extended to the International Nickel Co. for their assistance in furnishing the materials which were used in the experiments.

Resistance Welding Crossed Wires*

By Raymond C. Jones†

A study of the effect of welding variables, namely electrode force, time and current, upon the strength and appearance of crossed-wire welds was made. The scope of the project was confined to wires having a maximum diameter of 1/2 in. and a minimum of 1/8 in. using both cold-drawn and hot-drawn (basic) low-carbon steel. Each wire diameter considered was studied under the three conditions of setdown of 15, 30 and 50%, as the magnitude of the required variables is dependent upon the amount of setdown (per cent set down being arbitrarily defined as the per cent of one wire diameter lost during weld). A jig was developed for use in conjunction with a standard testing machine for breaking welded coupons and arriving at a measure of weld strength. Correlation of the observed data permitted the selection of welding variables which would consistently produce high-strength welds having sufficiently good appearance to meet most requirements.

Introduction

RESISTANCE welding of crossed wires may be defined as the fusion of wires or rods, lying one above the other with their lengths normal to each other, by the simultaneous application of current and pressure.

This phase of the resistance welding process has long been known and its use adopted extensively in many fields of metal fabrication. The production of such items as wire racks, novelties, gratings and many others has benefited by the inherent time, labor and cost saving characteristics of this process.

The use of resistance welding in this field may be grouped into three classifications according to the number of welds involved and the type of equipment used; fabrication of parts where single welds are made using rocker arm, press type or seam welders; manufacture of articles requiring a number of welds where a seam welder is employed making one or more welds at a time, but feeding the assembly through the machine, thus speeding up the operation; and the most prevalent type where a press welder is employed to produce a number of welds simultaneously.

That only a meager amount of published data is available concerning the proper choice of variables to be employed in conjunction with this process may be presumed to be the result of past experience indicating that this application is relatively insensitive to schedule. Such lack of information may also be attributed, in part, to the difficulty of testing welds of this geometry and the absence of standards with which to compare observed data.

* Scheduled for Twenty-Ninth Annual Meeting, A.W.S., Philadephia, Pa., week of Oct. 24, 1948.

† Sales Engineer, The Taylor-Winfield Corp. Warren, Ohio.

Objective

The program herein described was initiated with a desire to obtain more complete information relative to the effect of welding variables upon the end product. Specifically it was desired to determine what combination of welding time, electrode force and welding current would produce quality welds. As criteria of quality, both breaking load and appearance were considered.

The assumption that appearance would be of major importance is contingent upon the fact that the majority of applications in this category concern products where the weld is visible to the ultimate consumer. It must also be recognized that the expulsion of a large amount of unrestricted metal, as is the case in crossed-wire welding, will result in an undesirable appearance unless proper control is instituted.

The need for basic information upon which to predicate variables for more complex applications led to the restriction of work to the making of single welds using wires of equal diameter. It was felt that such information would be of immediate value and furnish a basis for future programs of investigation.

The scope of the program was further limited to the study of wires having a maximum diameter of 1/2 in. and a minimum diameter of 1/8 in. Although, arbitrarily chosen, this limit was felt to be broad enough to include the majority of applications in this field. Realizing that the magnitude of the variables required for a given wire size would be dependent upon the per cent of setdown, data was obtained for each of three setdowns: namely, 15, 30 and 50%. Here again, the arbitrary choice of limits was designed to provide data which would be of the greatest value.

Material

Data was desired for welding both cold-drawn and hot-drawn (basic) low-carbon steel wire. To insure reasonable uniformity of chemical analysis and physical properties, samples were submitted to the James Herron Laboratories of Cleveland, Ohio, for tests, the results of which are shown in Table 1.

Uniformity of surface condition was obtained by purchasing clean bright steel which had been oiled previous to shipment to prevent corrosion. Oil and accumulated dirt were removed just prior to welding by submerging the steel in carbon tetrachloride and wiping clean with a dry cloth or paper towel.

Equipment

Welding Machines

The wide range of variables necessitated the employment of a number of welding machines. All such equipment was of the press type, fully automatic, direct air

Table 1—Chemical Analysis and Physical Properties of Materials Used in Investigation

Wire Diam., In.	Cold-Drawn Wire: Ultimate Strength, Psi.	Elongation, %	Rockwell, B	Per Cent: C	Mn	P	S	Si	Hot-Drawn Wire: Ultimate Strength, Psi	Elongation, %	Rockwell B	Per Cent: C	Mn	P	S	Si
1/8	116,000	5	91	0.17	0.95	0.010	0.024	0.028	89,000	9	87	0.071	0.35	0.015	0.044	0.016
3/16	88,000	13	89	0.22	0.74	0.012	0.024	0.028	....	..	..	....	..	....	....	....
1/4	98,000	14	94	0.19	0.74	0.014	0.021	0.035	69,000	10	81	0.053	0.40	0.013	0.036	0.009
5/16	90,000	15	91	0.18	0.71	0.023	0.030	0.197	73,000	14	83	0.062	0.36	0.015	0.045	0.009
3/8	85,000	18	89	0.17	0.57	0.022	0.037	0.028	68,000	19	81	0.059	0.34	0.015	0.035	0.026
7/16	79,000	24	88	0.17	0.80	0.032	0.041	0.033	....	..	..	....	..	....	....	....
1/2	76,000	25	84	0.16	0.80	0.016	0.027	0.024	....	..	..	....	..	....	....	....

operated and designed for operation from a single-phase, 0-cycle, alternating-current supply. Each machine was equipped with a transformer having a tapped primary winding for adjustment of welding current. Finer adjustments were obtained through the medium of an auto-transformer connected across the primary of the main transformer.

Controls

The sequence of operations and the time duration of each was controlled through the use of standard non-synchronous welding controls employing electronic contactors. A phase-shifting heat control was incorporated with the electronic contactor as auxiliary equipment.

The use of the phase-shifting heat control with its inherent nonsinusoidal wave shape was felt to be justified due to the fine adjustment of welding current required to obtain predetermined percentages of setdown. In order to minimize the extent to which this nonsinusoidal wave might affect the results, it was never used below the 80% heat setting, with coarser adjustments obtained through the use of the auto-coil or the taps of the main transformer.

Electrodes

Flat, copper, water-cooled electrodes were used in all cases. The decision to adopt flat electrodes for use in this investigation was reached after considerable discussion with a number of welding engineers informed in this type of welding; the consensus of opinion being that flat electrodes were the most desirable for production purposes. It should be recognized, however, that although flat at the beginning of a specific data-recording period the faces of the electrodes rapidly deformed to the contour of the wire being welded, as would be the case in production.

A closer examination of the subject of electrodes brought to light the fact that this factor had no effect upon the required welding variables; however, due to the more intimate contact of the work with the electrode, where contoured dies are employed, this component of the work resistance is reduced, thus lowering the secondary voltage required for a given welding current. We may thus conclude that contoured dies will slightly reduce the power demand and minimize surface burning.

General Procedure

As previously mentioned, the broad purpose of the program was to provide information which would be of value to commercial users of resistance welding equipment in determining the correct variables for their application. A first assumption was that a fair appearance would be required for commercial use; a second assumption being that economic factors would require that the welding time be limited to 60 cycles (one second) or less.

Initial tests were concerned with cold-drawn low-carbon steel wire and welds were made using a predetermined time and per cent setdown. The electrode force was varied in increments consistent with the total value, maintaining constant the predetermined time and per cent setdown.

Evidence was at once presented indicating that a pleasing appearance could be obtained over a wide range of welding time provided the electrode force was properly adjusted. It was further noted that maximum strength

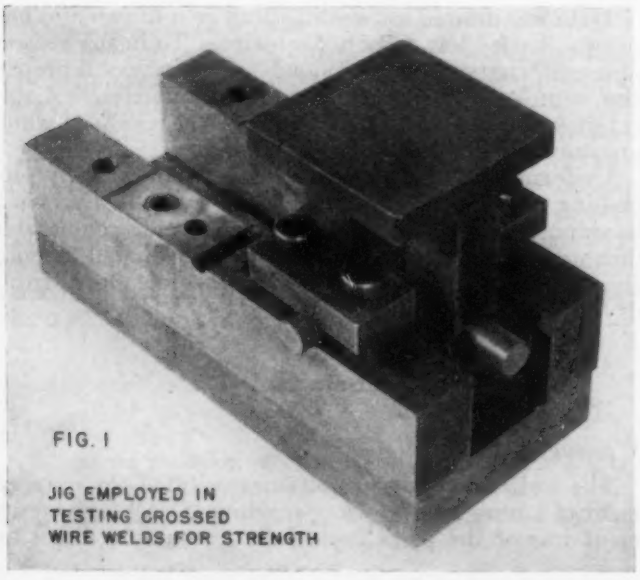


FIG. 1

JIG EMPLOYED IN TESTING CROSSED WIRE WELDS FOR STRENGTH

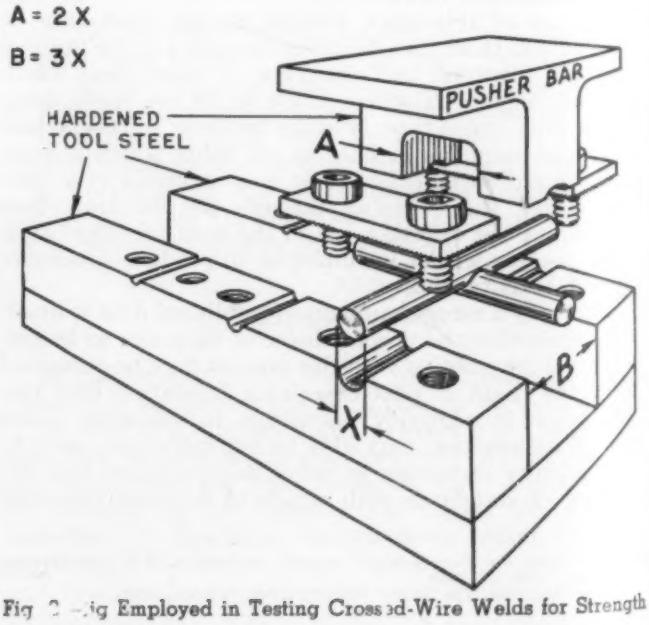


Fig. 2—Jig Employed in Testing Crossed-Wire Welds for Strength

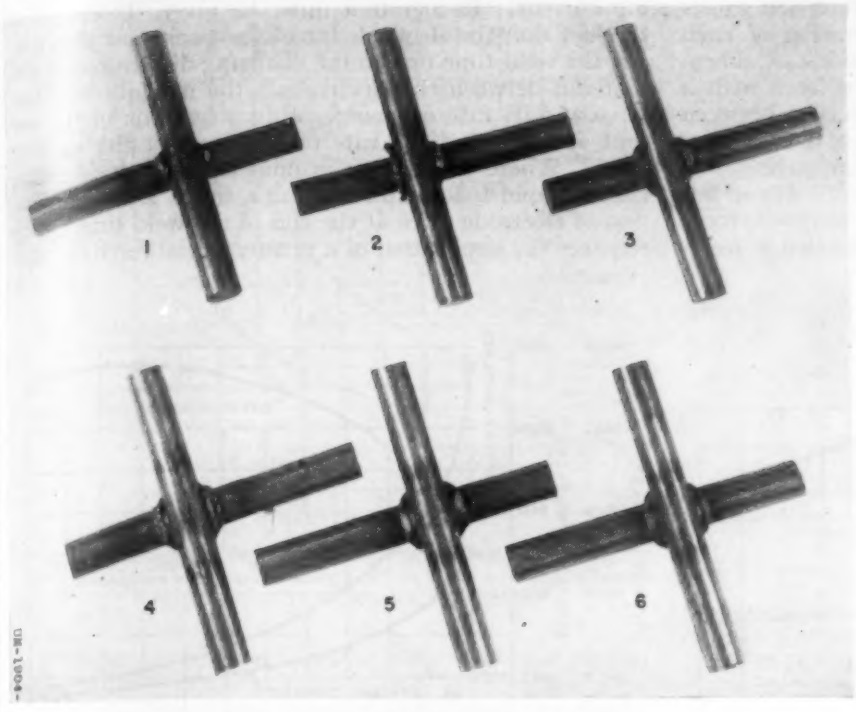


Fig. 3—Effect of Electrode Force on Appearance

Measurements

Weld Time.—The calibrations of the weld timer dials were checked by the use of a brush magnetic oscillograph before initiation of the welding program. Frequent checks of the weld time values throughout the investigation insured continued accuracy.

Welding Current.—All welding currents were determined by measurement of the primary current with a pointer-stop ammeter in conjunction with a current transformer and multiplying this value by the turns-ratio of the welding transformer. It will at once be realized that this results in the recorded values being the maximum rms. currents flowing during the weld time.

Realizing the possibility of introducing an error in this type of measurement due to the exciting current of the welding transformer, this value was measured under open circuit conditions and determined to be of such a low magnitude as to be insignificant.

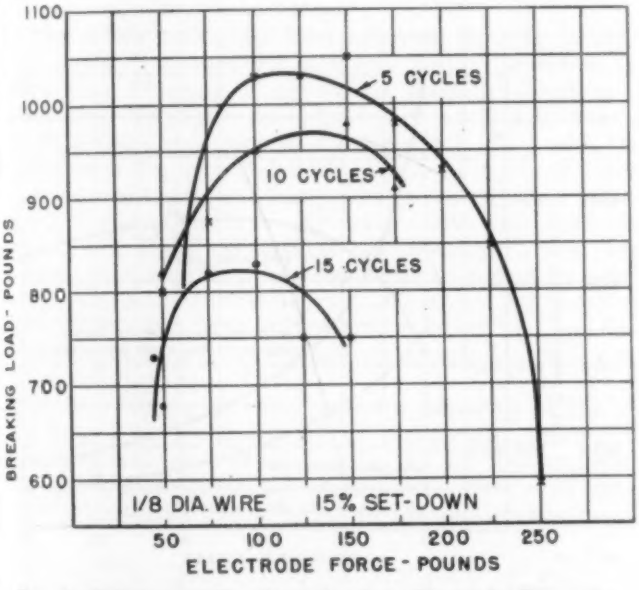


Fig. 4—Relation of Breaking Load to Electrode Force for Crossed-Wire Welds in Cold-Drawn Low-Carbon Steel

and pleasing appearance were coincident over a much narrower range of welding time.

In addition to the original assumptions, the balance of the tests were conducted in the vicinity of the minimum electrode force which would produce a satisfactory appearance. These points were determined by adjusting the electrode force until the desired appearance was obtained at a given time and per cent setdown.

Once this information was obtained, a similar investigation was started using hot-drawn low-carbon steel wire. It soon became evident that the current and electrode forces required for the same end results were very close to those obtained for cold-drawn wire. For this reason only a limited number of tests were made on hot-drawn low-carbon steel wire, these tests being confined to the same level of variables as were found necessary to the desired end results for cold-drawn steel.

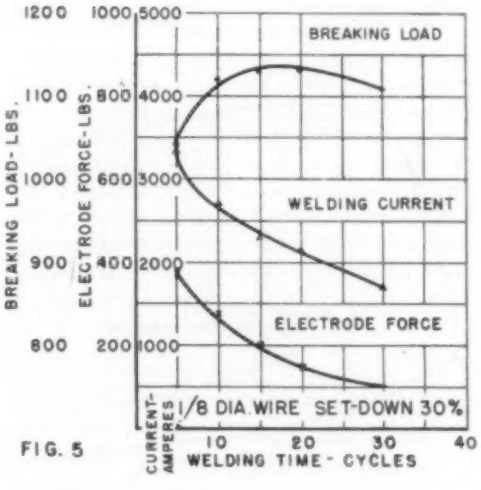


FIG. 5

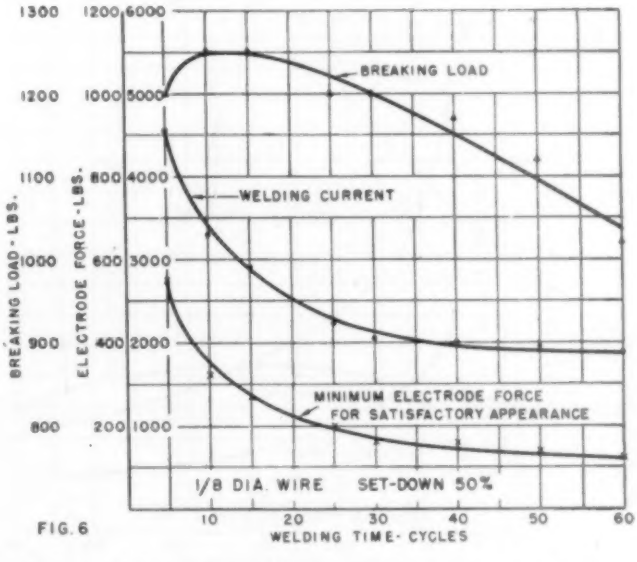


FIG. 6

Figs. 5 and 6—Relation of Required Schedules for Satisfactory Appearance and Resulting Breaking Load to Welding Time When Welding Cold-Drawn Low-Carbon Steel

Electrode Force.—The accuracy of the recorded values of electrode force was insured by calibration of each machine before the start of welding operations. Calibration consisted of measuring the electrode force with a General Electric welding force gage, inserted between the electrodes, while simultaneously noting the air pressure as indicated by a standard air pressure gage.

As a further precaution the squeeze period was so adjusted as to provide sufficient time for the electrode force to build up to the desired value before initiation of welding current. Recognition must be given, however, to the fact that the electrode force is not constant throughout the weld time due to the changing dimensions of the material between the electrodes; the magnitude of the force and its rate of change being a function of the per cent setdown and the rate of follow-up of the welding head. Where the change in dimension is considerable, lack of rapid follow-up results in a much lower application of electrode force at the end of the weld time which requires the application of a greater initial force as compensation,

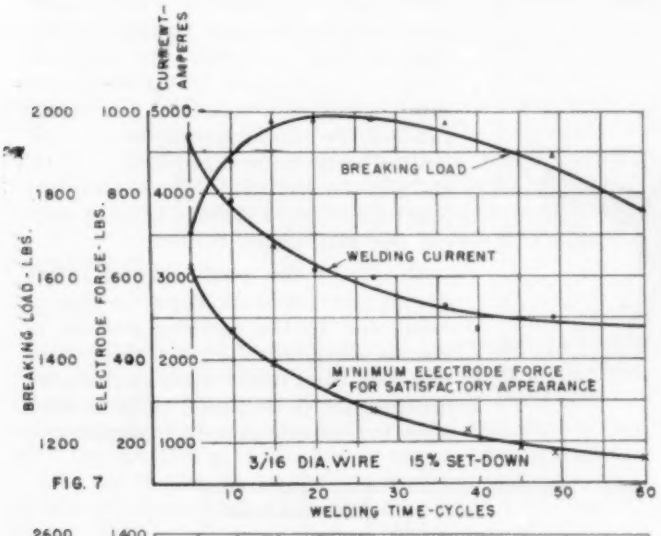


FIG. 7

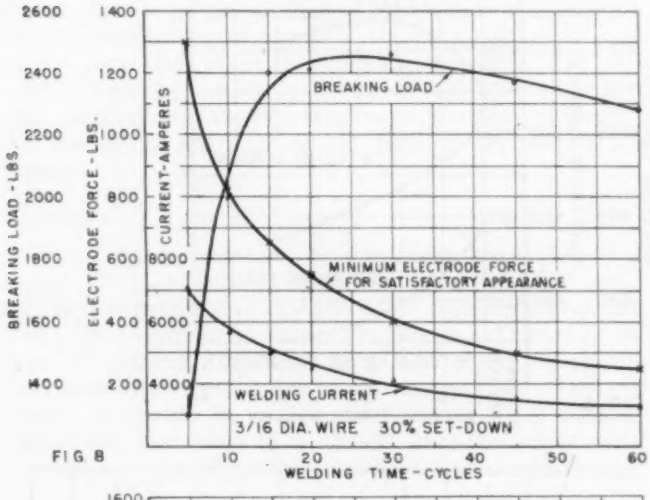


FIG. 8

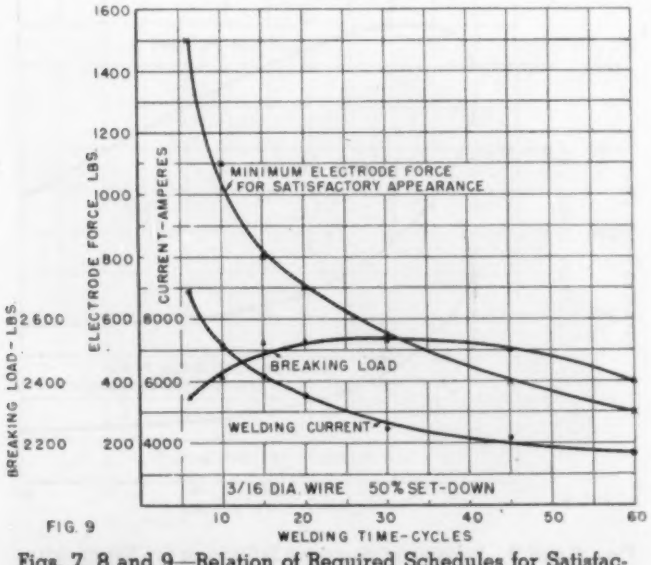


FIG. 9

Figs. 7, 8 and 9—Relation of Required Schedules for Satisfactory Appearance and Resulting Breaking Load to Welding Time When Welding Cold-Drawn Low-Carbon Steel

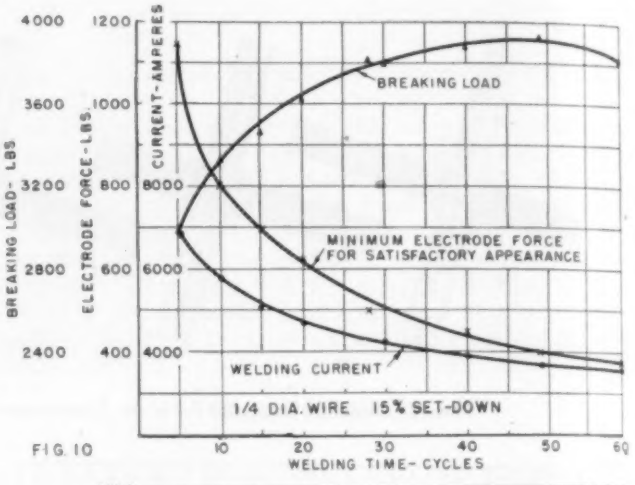


FIG. 10

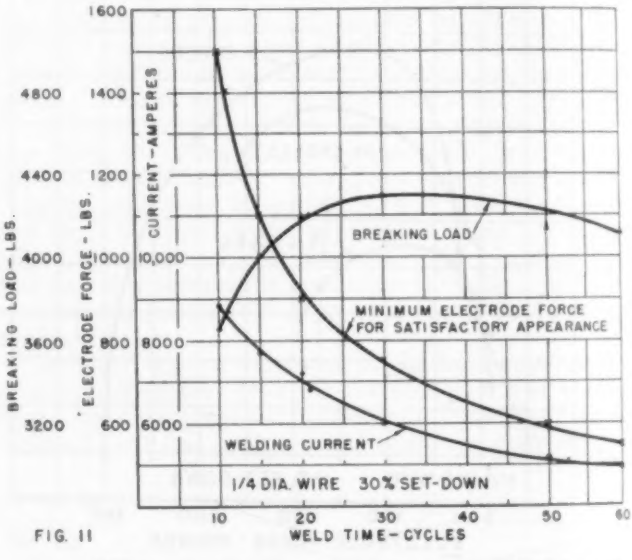


FIG. 11

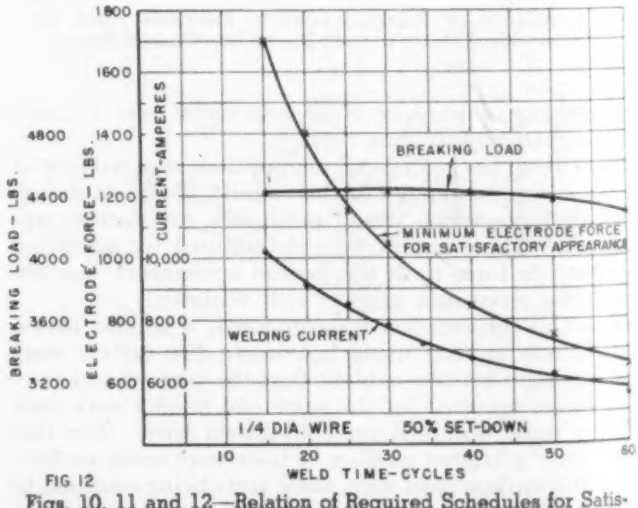


FIG. 12

Figs. 10, 11 and 12—Relation of Required Schedules for Satisfactory Appearance and Resulting Breaking Load to Welding Time When Welding Cold-Drawn Low-Carbon Steel

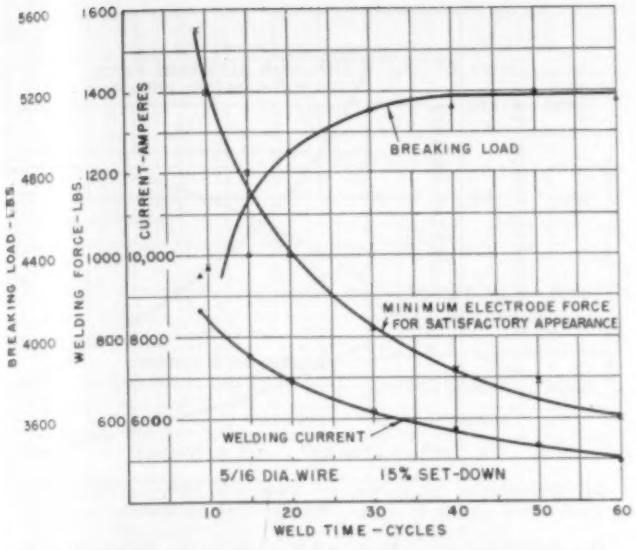


Fig. 13—Relation of Required Schedules for Satisfactory Appearance and Resulting Breaking Load to Welding Time When Welding Cold-Drawn Low-Carbon Steel

Breaking Load.—Considerable time was expended in determining a practical method of measuring the force required to break this type of weld. The jig finally adopted (Fig. 1) was felt to be capable of producing the desired results without being too intricate for use in production work.

The values measured by employing this jig in conjunction with a standard hydraulic testing machine, although not absolute tensile values, provide a method of comparing relative strengths. An outline drawing, showing the dimensions of the jig which vary with the diameter of the wire under test, is shown in Fig. 2. Examination of the jig will lead to the conclusion that values closer to the absolute tensile value could have been obtained had these dimensions been smaller. This was realized at the outset, but consideration had to be given to the amount of extruded metal and to the width of the pusher bar; the values shown being the smallest which could be used with adequate margin for these considerations.

As any change in the original dimensions of the jig was found to materially affect the results, the use of hardened tool steel in fabricating the jig was necessary in order to maintain initial dimensions. The use of softer material resulted in the edges of the pusher bar mushrooming, thus enlarging the opening which in turn increased the bending moment with an accompanying decrease in the amount of force required to break the weld.

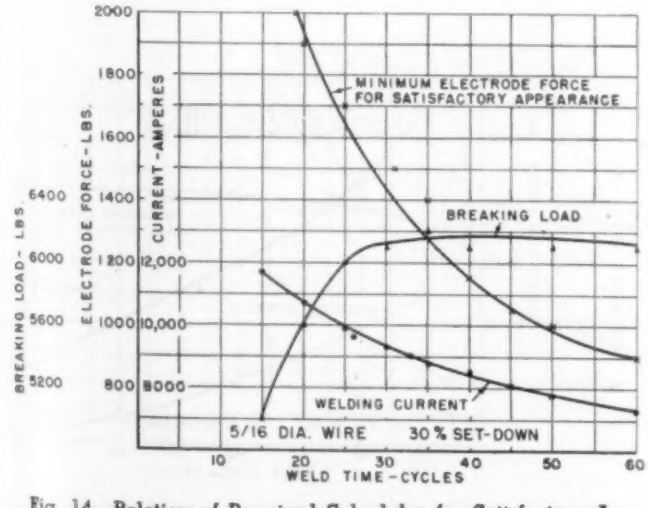


Fig. 14—Relation of Required Schedules for Satisfactory Appearance and Resulting Breaking Load to Welding Time When Welding Cold-Drawn Low-Carbon Steel

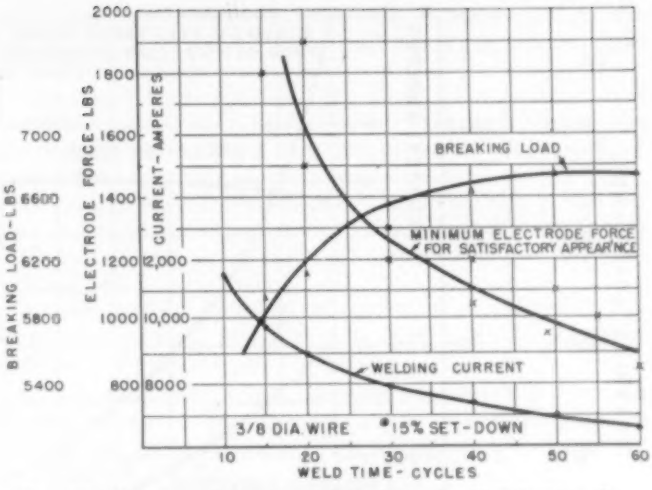


Fig. 15—Relation of Required Schedules for Satisfactory Appearance and Resulting Breaking Load to Welding Time When Welding Cold-Drawn Low-Carbon Steel

Results

Low-Carbon Cold-Drawn Steel Wire

Appearance.—Early in the investigation it became quite evident that the resulting appearance of welds made at a fixed welding time and per cent setdown progressed through a definite cycle as the electrode force was gradually increased from a low value. This same cycle was noted for every wire diameter and per cent setdown investigated, except $^1/_8$-in. diam. wire set down 15%. It is reasonable to assume that the same conditions existed here, but were not discernible due to small volume of displaced metal.

An examination of Fig. 3 will permit the reader to gather a general impression of the effect of electrode force upon weld appearance. However, it must be realized that it was not possible to present every obtainable condition with the variations which occur with slight adjustments of electrode force.

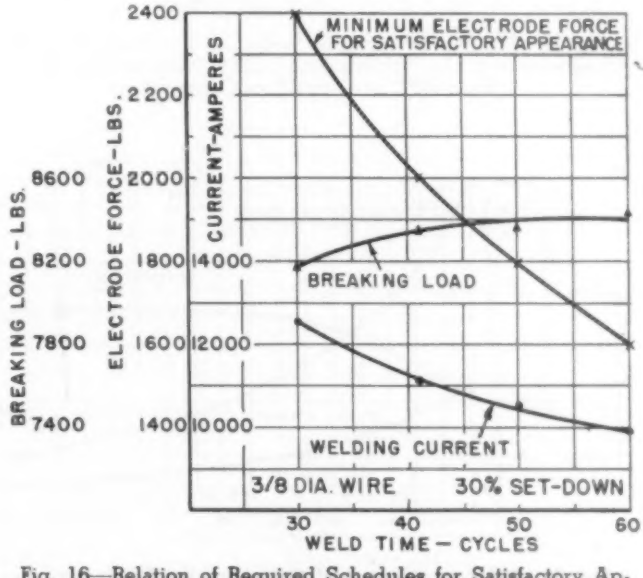


Fig. 16—Relation of Required Schedules for Satisfactory Appearance and Resulting Breaking Load to Welding Time When Welding Cold-Drawn Low-Carbon Steel

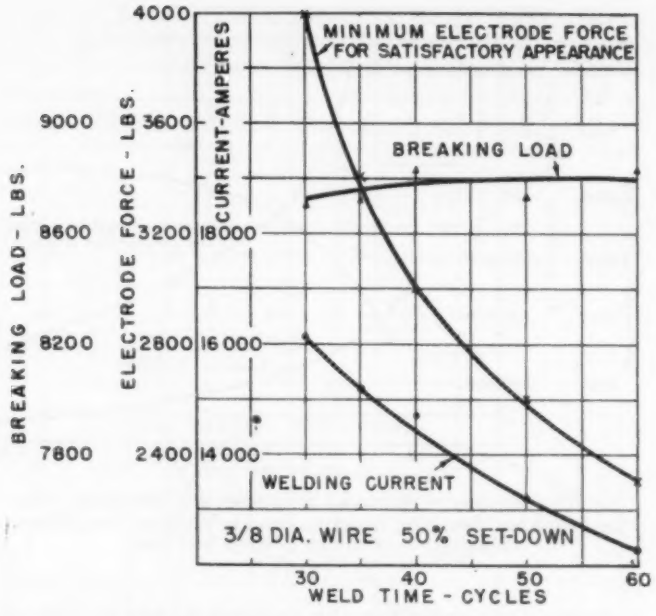


Fig. 17—Relation of Required Schedules for Satisfactory Appearance and Resulting Breaking Load to Welding Time When Welding Cold-Drawn Low-Carbon Steel

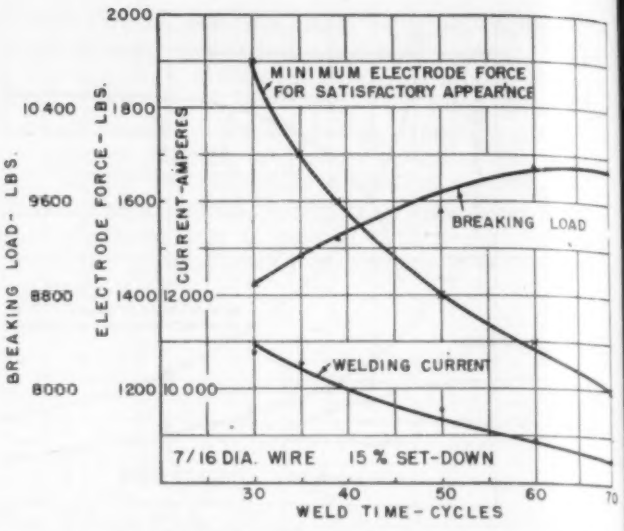


Fig. 18—Relation of Required Schedules for Satisfactory Appearance and Resulting Breaking Load to Welding Time When Welding Cold-Drawn Low-Carbon Steel

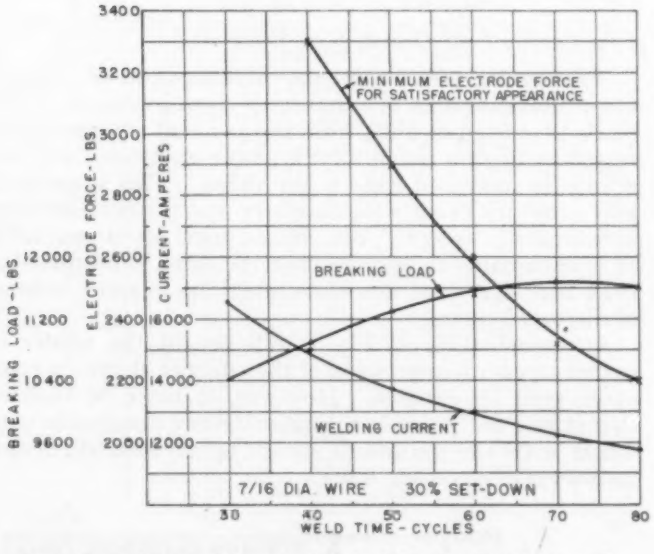


Fig. 19—Relation of Required Schedules for Satisfactory Appearance and Resulting Breaking Load to Welding Time When Welding Cold-Drawn Low-Carbon Steel

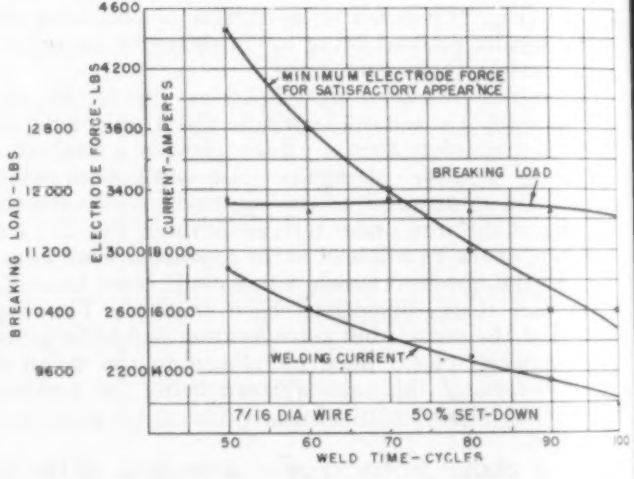


Fig. 20—Relation of Required Schedules for Satisfactory Appearance and Resulting Breaking Load to Welding Time When Welding Cold-Drawn Low-Carbon Steel

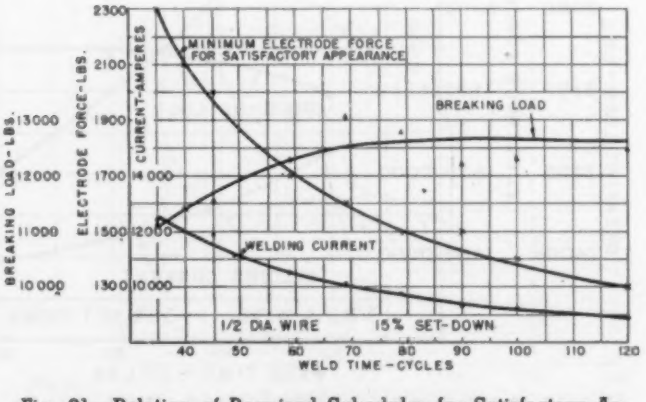


Fig. 21—Relation of Required Schedules for Satisfactory Appearance and Resulting Breaking Load to Welding Time When Welding Cold-Drawn Low-Carbon Steel

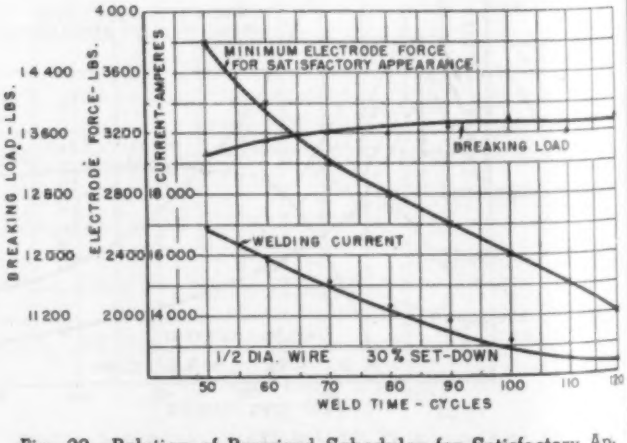


Fig. 22—Relation of Required Schedules for Satisfactory Appearance and Resulting Breaking Load to Welding Time When Welding Cold-Drawn Low-Carbon Steel

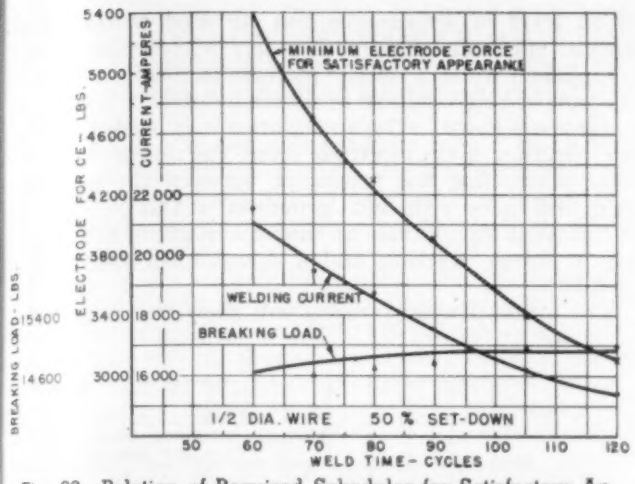


Fig. 23—Relation of Required Schedules for Satisfactory Appearance and Resulting Breaking Load to Welding Time When Welding Cold-Drawn Low-Carbon Steel

The cycle of appearance may be described as follows:

1. Low electrode forces were accompanied by spitting and the extrusion of globules of molten metal which clung to the periphery of the weld in a very nonuniform pattern (note weld *1* in Fig. 3).

2. An increase in electrode force resulted in extruded metal of a less molten state with continued nonuniformity and cracks appearing about the edges.

3. Further increase in electrode force produced extruded metal with a more uniform appearance than formerly obtained.

A general impression of the conditions as described in steps 2 and 3 may be had from weld *2* in Fig. 3, the uniformity and number of cracks appearance depending upon the magnitude of the electrode force.

4. Additional force caused the extruded metal to part at the center line of weld showing two distinct layers with their edges cracked in a nonuniform pattern (see welds *3* and *4* in Fig. 3).

5. As further increase of electrode was applied the layers of extruded metal became one again with cracks appearing about the periphery.

6. A relatively small increase of electrode force at this point caused the extruded metal to become uniform with a few loose feathers of metal about the periphery (note weld *5*, Fig. 3).

7. Increasing the electrode force above this level reduced the number of feathers clinging to the weld until none were left, while further increases of force served only to enhance an already pleasing appearance.

After considerable study and discussion it was decided that the level of appearance, described in the sixth step and shown in Fig. 3 as weld *5*, was the most desirable for practical applications. This opinion was based upon evidence indicating that such an appearance could be obtained without loss of strength and a comparison of this condition with welds from production lines.

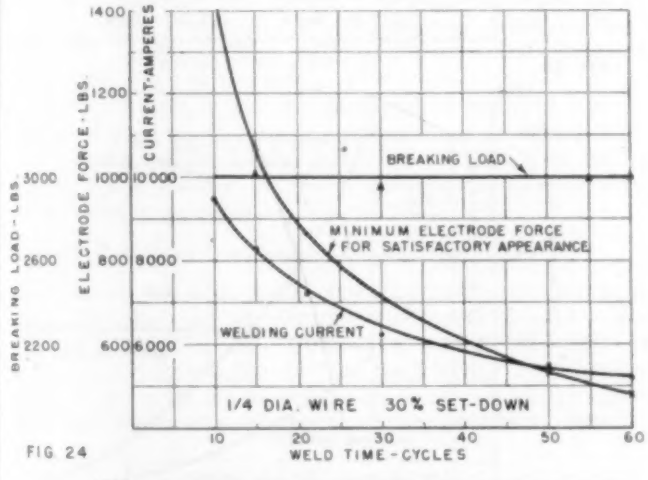


FIG. 24

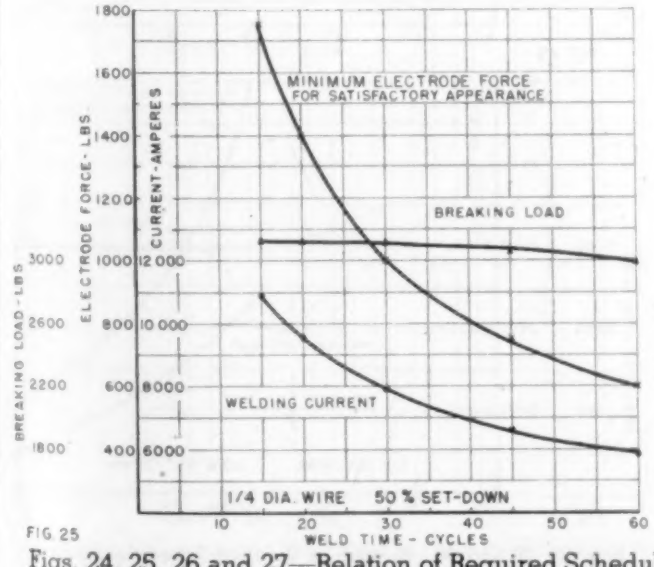


FIG. 25

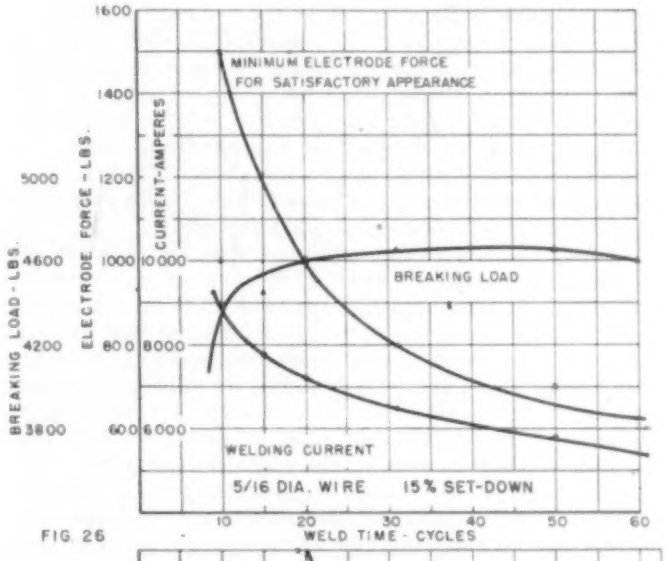


FIG. 26

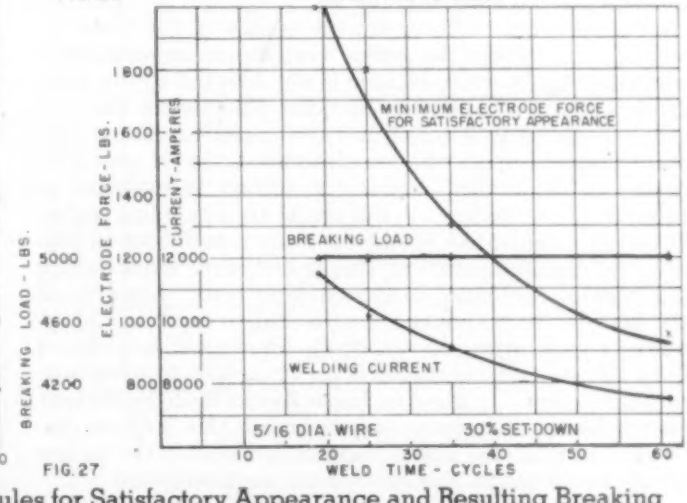


FIG. 27

Figs. 24, 25, 26 and 27—Relation of Required Schedules for Satisfactory Appearance and Resulting Breaking Load to Welding Time When Welding Hot-Drawn (Basic) Low-Carbon Steel

It is the writer's opinion that welds having this appearance will be suitable for most applications; moreover, where strength is a factor and appearance requirements are more severe, appearance requirements can be met by buffing with a soft wire brush. Where strength is not of particular importance, greater electrode force can be used, thus eliminating the small feathers of extruded metal entirely. However, if the electrode force is increased beyond this level, a sacrifice will be made in strength and more and more welds will be found fracturing across the weld line as greater forces are employed.

Data.—The effect of welding time upon the required schedules for producing welds of satisfactory appearance (as previously described) in cold-drawn low-carbon steel and the strengths of the resulting welds are shown in Figs. 5 to 23, inclusive. It will be noted that this group does not include welds in $^1/_8$-in. diam. wire, set down 15%. It was found that the small volume of metal displaced in this case made it practically impossible to distinguish between appearance levels without the aid of a miscroscope. For this reason appearance was not considered in the selection of a recommended schedule for welding $^1/_8$ in. diameter with a set down of 15%. Data for this case are shown in Fig. 4 with the measured breaking loads plotted against the electrode forces used at various fixed welding times.

Welding Time.—The range of weld time over which satisfactory appearance and maximum weld strength are coincident becomes greater as the wire diameter and/or the per cent setdown increases, while the minimum time required becomes longer as the wire diameter increases and is not materially affected by the per cent setdown.

Maximum strength can be obtained at weld times of lesser duration by a corresponding decrease in electrode force; however, if the weld time is shortened to too great an extent a point is reached where maximum strength cannot be obtained at any electrode force. A further result of the use of relative short weld time is a brittle weld structure; a characteristic to be expected when heating and cooling rates are too great.

Welding Current.—The welding current was found to be practically constant over a wide range of electrode force with the wire diameter, per cent setdown and welding time maintained constant. This may at first appear contrary to the basic laws of resistance welding; it being a known fact that the heat required for raising the temperature of the work to the plastic range is a function of the current, resistance and time involved. When the electrode force is increased, thereby decreasing the contact resistance, it is natural to assume that the current must be raised; however, in crossed-wire welding the heat required for pushing the wires together is controlled by the resistance offered by the bodies of the wires involved rather than the contact resistance and this component of the work resistance is not affected by the electrode force. Whether fusion takes place when the contact resistance is reduced and the current remains constant depends upon whether the summation of heat generated in the bodies and at the surface is sufficient to raise the temperature of the metal to a bonding value. If the heat generated within the body is sufficient to produce welding temperature, fusion will occur even though the contact resistance is approaching zero; however, if the heat in the bodies is not sufficient to produce the required temperature, the electrode force must be reduced until the contact resistance is great enough to overcome this deficiency. It must be remembered that the current cannot be raised in order to accomplish this purpose due to the fact that this would cause added heat in the bodies which would result in a greater per cent setdown.

The above analysis explains evidence indicating that electrode forces greater than the minimum required for a given level of appearance can be used without detrimental effect upon strength where 50% setdown is accomplished while a similar increase in electrode force in the case of 15% setdown results in a decrease in strength.

Electrode Force.—The appearance of crossed-wire welds is a function of the electrode force, the magnitude of the force controlling the resistance between the work surfaces and thereby the heat generated at this point. Lack of sufficient force causes an undue amount of heat resulting in severe spitting and a nonuniform expulsion of metal.

The accompanying graphs will show the variation of

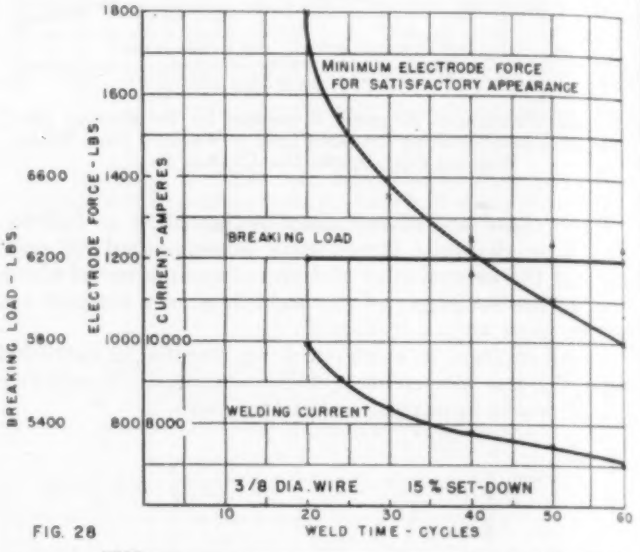


FIG. 28

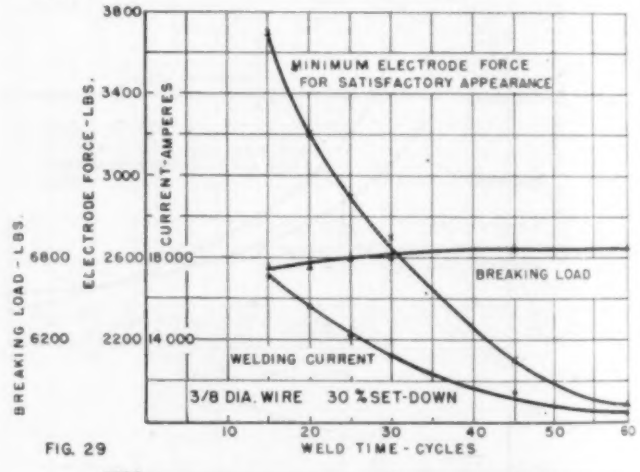


FIG. 29

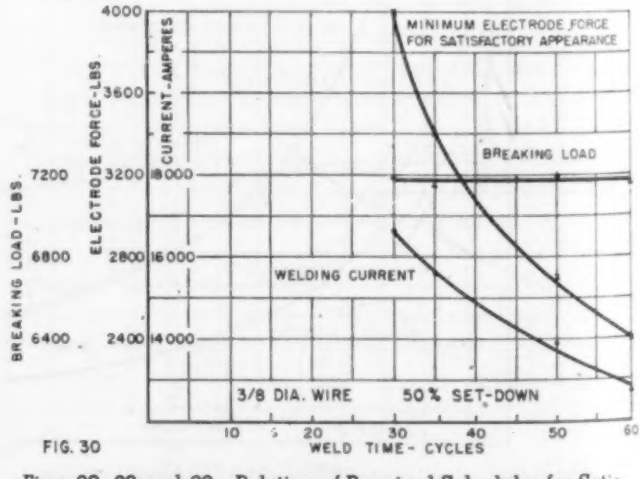


FIG. 30

Figs. 28, 29 and 30—Relation of Required Schedules for Satisfactory Appearance and Resulting Breaking Load to Welding Time When Welding Hot-Drawn (Basic) Low-Carbon Steel

electrode force with time where the end result is a crossed-wire weld of satisfactory appearance. It will be noted that these curves approach the hyperbola in shape with the required force approaching infinity with too short a welding time.

Variation in the per cent setdown with a given weld schedule was found to increase as the electrode force was decreased until it was almost impossible to maintain a given dimension when extremely low electrode forces were used.

The effect of electrode force upon strength is dependent upon the welding time, wire diameter and per cent setdown involved. It was found in all cases that as the welding time became shorter it was not possible to obtain welds of high strength at electrode forces sufficiently high to produce satisfactory appearance. The range over which satisfactory appearance and maximum strength were coincident became greater both with an increase in per cent setdown and with an increase in wire diameter; further it was noted that the electrode force could be increased over the minimum value for satisfactory appearance to a greater extent when welding heavy stock or lighter stock at a greater per cent setdown without an accompanying decrease in weld strength.

Breaking Load.—The breaking load, determined as previously explained, was found to be reasonably consistent and not affected greatly by a small change in any one of the welding variables over a large range. This should not lead to the conclusion that welding variables can be chosen at random; an example of the serious effect of attempting to weld at too short a time is shown in Fig. 8. In addition to the loss of average strength shown on the curve inconsistencies in strength were encountered. A similar effect will result when the electrode force is too high or too low.

When comparing the weld strength of welds in a given diameter wire at the various percentages of setdown investigated it will be noted (Figs. 7, 8 and 9, for example) that a much greater change in strength occurs between 15 and 30% than between 30 and 50%.

Low-Carbon Hot-Drawn (Basic) Steel Wire

Appearance.—The same general relationship between electrode force and appearance was found to exist when welding hot-drawn low-carbon steel wire as was noted in welding cold-drawn low-carbon steel wire. Appearance levels were very much alike and occurred at the same electrode forces where other conditions were equal.

Data.—Graphical representation of the data accumulated while welding hot-drawn low-carbon steel wire is shown in Figs. 24 to 30, inclusive. This group of curves is based upon the minimum electrode force which will result in a satisfactory appearance (note weld *5*, Fig. 3).

Welding Time.—Maximum strength and satisfactory appearance were found to be coincident over a greater range of welding time than was true when welding cold-drawn low-carbon steel. However, welds at relatively short weld time had a tendency to brittleness and fractured at lower than maximum strength values.

Welding Current.—The required welding current was found to be a function of the welding time, being practically constant over a wide range of electrode force when the time and per cent setdown were fixed (as was true when welding cold-drawn low-carbon steel wire). The magnitude of the required current was found to be slightly greater than that measured when welding cold-drawn low-carbon steel wire.

The need for more current in welding hot-drawn low-carbon steel may be attributed to the lower resistance presented by this material. That the resistance was lower is evidenced by the fact that the greater current used was obtainable at a lower secondary voltage than was necessary for the same schedule when welding cold-drawn low-carbon steel wire with a lesser current.

Electrode Force.—The electrode force necessary for obtaining satisfactory appearance when welding hot-drawn low-carbon steel wire was found to be the same as that required for cold-drawn low-carbon steel wire when other conditions were equal.

Breaking Load.—The measured loading required for fracturing welds in hot-drawn low-carbon steel wire was found to be considerably lower than was necessary for fracturing welds in cold-drawn low-carbon steel wire, as would be expected due to the difference in the ultimate strengths of the parent metals (note Table 1).

Measured breaking loads were found to be more consistent both from weld to weld at the same schedule and between groups of welds made at different schedules than was found for low-carbon cold-drawn steel wire.

Conclusions

1. Satisfactory appearance can be obtained without loss of strength by the proper selection of welding variables.

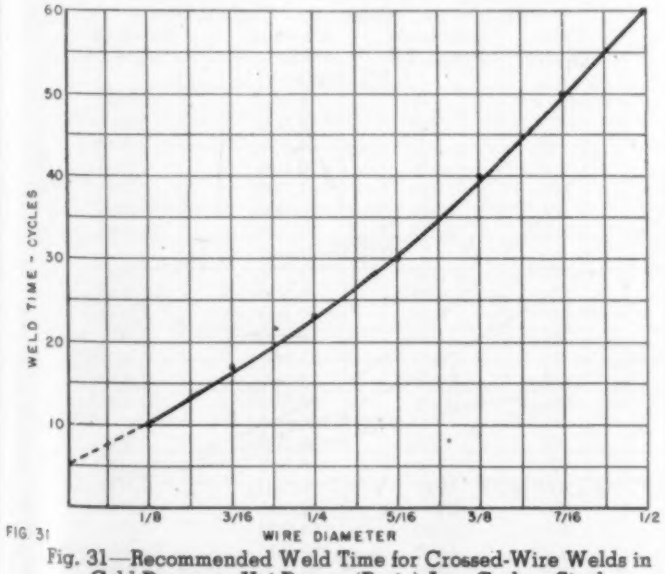


FIG. 31

Fig. 31—Recommended Weld Time for Crossed-Wire Welds in Cold-Drawn or Hot-Drawn (Basic) Low-Carbon Steel

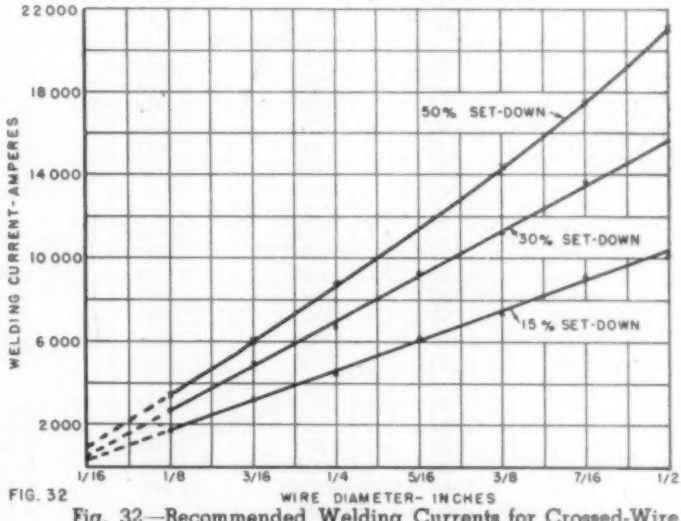


FIG. 32

Fig. 32—Recommended Welding Currents for Crossed-Wire Welds in Cold Drawn Low-Carbon Steel

2. The weld time is the most important variable; the welding current and electrode force required being dependent upon the choice of weld time.

3. The welding current is practically constant over a large range of electrode force, other factors remaining constant.

4. Cold-drawn and hot-drawn (basic) low-carbon steel wire require the same electrode force for satisfactory appearing crossed-wire welds where other variables are fixed.

5. The welding currents for crossed-wire welds in hot drawn (basic) low-carbon steel wire are slightly higher than those encountered when welding cold-drawn low-carbon steel wire.

6. Crossed-wire welds in cold-drawn low-carbon steel wire have greater strength than their equivalent in hot-drawn (basic) low-carbon steel wire.

7. No great strength advantage is gained by setting wires together more than 30%.

APPENDIX

Recommended Schedules

The choice of welding variables becomes a problem of economic factors. It is the writer's opinion that the choice of variables should be such that maximum strength, together with good appearance, can be developed using a minimum length of weld time and minimum weld force. This selection should be tempered by judgment where the use of the minimum time would necessitate values occurring on the steeper slopes of the force and current curves and so become relatively critical schedules. For example, although evidence indicates that welds of maximum strength could be obtained in 1/4-in. wire at 30% setdown at 10 to 15 cycles, the writer would consider 20 to 25 cycles a better choice due to the rapid rise of required electrode force at the shorter time. This opinion is based upon the fact that welds made at the shorter time will not be consistent unless greater than normal control in production is exercised.

With all of these considerations in mind, the writer chooses the schedules shown in Table 2. It will be noted that the same welding time has been chosen for all per cent setdowns in a given diameter and that the weld time and electrode force are the same for both cold-drawn and hot-drawn (bright basic) low-carbon steel.

As an example of the procedure followed in determining the values tabulated in Table 2, note Figs. 10, 11 and 12. The straight portion of the strength curve for 15% setdown, Fig. 10, extends from 23 cycles to 60 cycles. The writer chose 23 cycles because schedules of shorter time duration indicated considerable lower strength values. Figures 11 and 12 indicate that for 30 and 50% setdown a shorter weld time could be used; however, an examination of the electrode force curves, same figures, show them to be relatively steep at these shorter welding times and for this reason the writer chose the same welding time as had been previously chosen for 15% setdown.

Having determined the most desirable welding time the electrode force and welding current were fixed by the assumed conditions of appearance and setdown.

Proposal for Future Investigation of the Resistance Welding of Crossed Wires

The previously described investigation dealt with the resistance welding of crossed wires between the limits of 1/8 and 1/2 in. diameter; where single welds of equal diameter wire were welded together and where recommended schedules were determined for producing welds of adequate strength and satisfactory appearance.

Due to the number of applications in this field which require the welding of smaller diameter wires, wires of unequal diameter and multiple welds with many variations, it is desirable to continue this investigation. Such a program should include part or all of the following points:

1. Welding wires of 1/16-in. diameter together.
2. Single welds using wires of unequal diameter.
3. Single welds using wires of equal diameter where the final diameter at the weld is equal to the diameter of one wire (100% setdown).
4. Multiple welds.

Table 2—Recommended Schedules

Wire Diam., In.	Cold-Drawn Low-Carbon Steel: Time, Cycles	Electrode Force, Lb.	Current, Amp.	Strength, Lb.	Hot-Drawn (Basic) Low-Carbon, Steel: Time, Cycles	Electrode Force, Lb.	Current, Amp.	Strength, Lb.
		15% Setdown				15% Setdown		
1/8	10	125	1,800	975	10	125	1,850	750
3/16	17	360	3,300	2,000	17	360	3,500	1,500
1/4	23	580	4,500	3,700	23	580	4,900	2,800
5/16	30	825	6,200	5,100	30	825	6,600	4,600
3/8	40	1100	7,400	6,700	40	1100	7,700	6,200
7/16	50	1400	9,300	9,600	50	1400	10,000	8,800
1/2	60	1700	10,300	12,200	60	1700	11,000	11,500
		30% Setdown				30% Setdown		
1/8	10	260	2,650	1,125	10	260	2,770	850
3/16	17	600	5,000	2,400	17	600	5,100	1,700
1/4	23	850	6,700	4,200	23	850	7,100	3,000
5/16	30	1450	9,300	6,100	30	1450	9,600	5,000
3/8	40	2060	11,300	8,350	40	2060	11,800	6,800
7/16	50	2900	13,800	11,300	50	2900	14,000	9,600
1/2	60	3400	15,800	13,600	60	3400	16,500	12,400
		50% Setdown				50% Setdown		
1/8	10	350	3,400	1,250	10	350	3,500	900
3/16	17	750	6,000	2,500	17	750	6,300	1,800
1/4	23	1240	8,600	4,400	23	1240	9,000	3,100
5/16	30	2000	11,400	6,500	30	2000	12,000	5,300
3/8	40	3000	14,400	8,800	40	3000	14,900	7,200
7/16	50	4450	17,400	11,900	50	4450	18,000	10,200
1/2	60	5300	21,000	14,600	60	5300	22,000	13,000

Welding Wires of 1/16-In. Diameter Together

The attached graphs, Figs. 31 to 36, showing the recommended schedules for welding wires of greater diameter, have been extended to provide data for the initiation of this project. No great accuracy is claimed for the extended portion of these curves; however, they will provide sufficiently accurate information to guide investigators in the selection of equipment and determining a starting point.

Although previous data were concerned with schedules which produced welds having a predetermined appearance, it will in all probability be found that recommended schedules for 1/16-in. diam. wire must be based wholly on strength due to the small amount of extruded metal involved. It appears to the writer that the volume of displaced metal will be so small as to render it impossible (as it was in the case of 1/8-in. diam. wire, set down 15%) to distinguish appearance levels without the aid of a microscope and that appearance levels determined in this manner will have no practical significance.

The writer would recommend that the investigation of this subject be confined to multiple welds rather than single ones. This opinion is based upon the fact that it is difficult to obtain and accurately vary electrode forces of the low magnitude required and that the welding of 1/16-in. diam. wire is nearly always done in multiple.

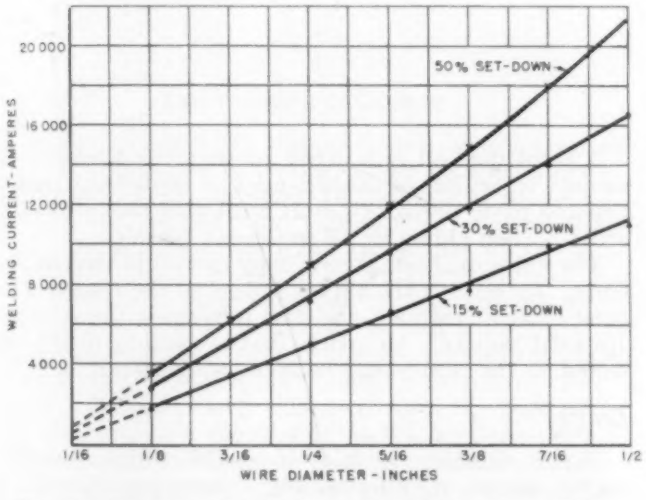


Fig. 33—Recommended Welding Current for Crossed-Wire Welds in Hot-Drawn (Basic) Low-Carbon Steel

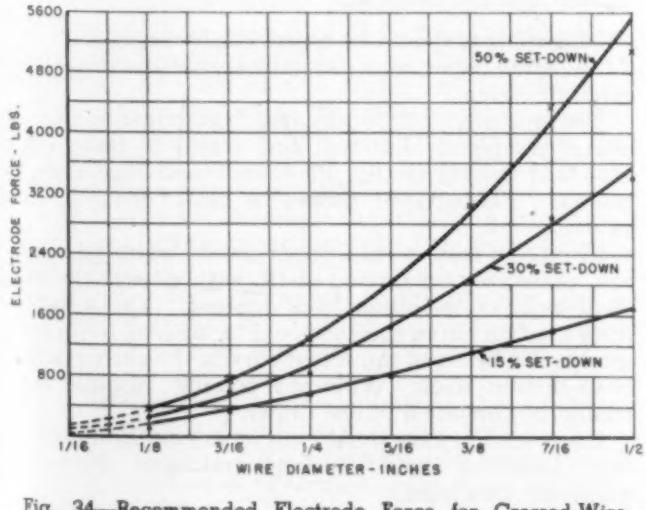


Fig. 34—Recommended Electrode Force for Crossed-Wire Welds in Cold-Drawn or Hot-Drawn (Basic) Low-Carbon Steel

Single Welds Using Wires of Unequal Diameter

The per cent setdown and the variable dimensions of the jig for breaking welding specimens previously described (Fig. 2) should be based upon the wire having the smaller diameter. This procedure will lead to a minimum of distortion, thus providing breaking load data more nearly coincident with the absolute tensile strength.

It is the writer's opinion that the electrode force, welding current and welding time required for welds of this type will be approximately the same as those required for the same per cent setdown using two wires of the smaller diameter. For this reason it would be recommended that any such investigation be started using data taken from the original investigation.

Single Welds of Equal Diameter Wires Set Together 100%

As it was found that the welding time remains constant for wires of equal diameter regardless of per cent setdown, in the original investigation concerning wires setdown 50% or less, the writer would recommend the initiation of a program concerning 100% setdown welds using the weld times as indicated in Fig. 31.

From an economic viewpoint the electrode force required for satisfactory appearance, at the weld time indicated by Fig. 31, when setting wires together 100% may demand a machine with a purchase price not justifiable for many applications of this type. In consideration of

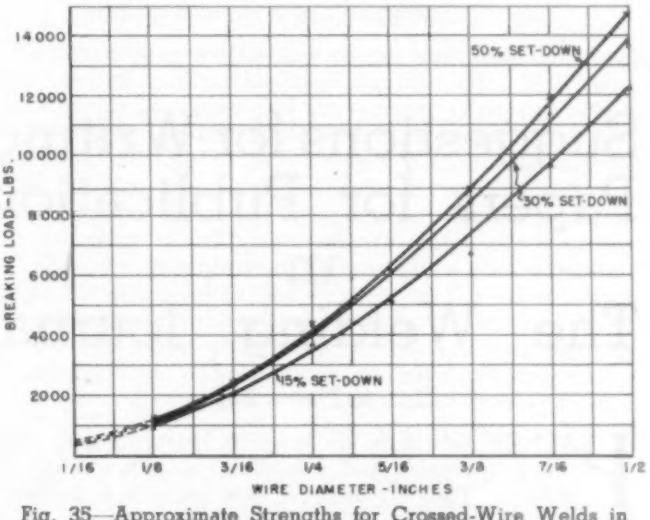


Fig. 35—Approximate Strengths for Crossed-Wire Welds in Cold-Drawn Low-Carbon Steel

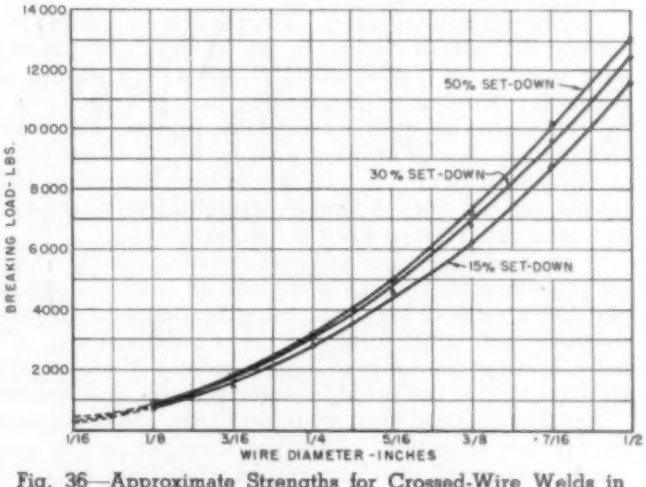


Fig. 36—Approximate Strengths for Crossed-Wire Welds in Hot-Drawn (Basic) Low-Carbon Steel

this point it would be well to consider this problem from two basic approaches:

1. Data to be obtained using the recommended time as found in the original investigation, or finding this time inadequate for the desired results (high strength welds and satisfactory appearance) with the shortest welding time required for producing the desired results.
2. Welding schedules based upon electrode forces obtainable in smaller machines. Such a procedure would lead to longer welding time and in the case of the heavier diameter wires necessitate the use of pulsation welding.

Some difficulties may be encountered in obtaining a final weld diameter equal to the diameter of one weld. It has been the writer's experience in welding $^1/_2$-in. diam. wire that it is not possible to set down 100% completely without considerable distortion of the parent metal. In order to circumvent this distortion many applications are so designed that the final diameter is not quite as small as the diameter of one wire. The writer would suggest that this practice be followed and that the limit be placed at 90% rather than 100% setdown.

Multiple Welds

It is the writer's opinion that the data accumulated in the original investigation concerning single welds may be used for determining schedules involving multiple welds. To obtain the schedule for a given application, the welding current and electrode force shown for a single weld may be multiplied by the number of welds required while the welding time shown will remain the same. In order to conserve time and money the writer would recommend that an attempt be made to substantiate this theory before undertaking any further investigation.

Acknowledgment

The author wishes to express his appreciation to the Management of The Taylor-Winfield Corp. for the use facilities necessary to the completion of this work and to his colleagues for their valuable aid and suggestions.

Suggestions for Writing Papers for Publication in The Welding Journal

How to Plan a Paper

PAPERS should be on subjects interesting to engineers, operators and executives in the welding industry. They should give new facts, new methods, experimental results or important conclusions about design, technique, jigs, fixtures, construction, operation or maintenance.

"Remember the reader!" The purpose of a paper is to convey the author's ideas to the reader. This is done with words, and is most effective when done simply and concisely. Readers' understanding may be helped greatly by the correct use of understandable words. The author should have clearly in mind *what* he wants to say before starting his paper. Then he should begin where his story begins; tell his story in simple, straightforward style and in logical order; stop when it has been told.

A good advance plan will make writing easier. A simple procedure that works is to make an outline of the paper, like a table of contents, using headings for the main divisions and subheadings to cover subdivisions. This helps arrange the ideas in logical order. Then, to write the paper, fill in the suitable material under each heading.

Another method is to write on cards. Sort the cards into proper sequence. Then the thoughts on the cards can be expanded into paragraphs expressing fully your ideas.

A third method is to write all that you know on the subject regardless of proper order or sequence; then to clip and paste this rough draft until your thoughts are in order. Then eliminate all irrelevant matter.

The value of short, precise copy cannot be overemphasized. It conveys the author's ideas to the reader in the most efficient manner, and also minimizes the length of JOURNAL papers. An article that is too long may be rejected, or the author may be asked to shorten it.

Length

Papers should be as short as possible without omitting useful, interesting information. Many papers suffer in clarity from too many words, or from words that are too long or too indefinite.

Manuscript and Drawings

Manuscripts should be typed, double spaced, on $8^1/_2$ x 11-in. white paper, with any tables, charts or drawings on separate sheets.

For printing, all drawings and charts must be clear and sharp, completely lettered, and drawn in India ink on standard tracing cloth. Photostats and blueprints will not do. Photographs should be clear, distinct, glossy prints.

Curves on cross-section paper should be traced in black ink, preferably on tracing cloth, with all but the major (half-inch) cross-section lines omitted. The weights of lines used on curve sheets should be such as to provide a graduation between the actual curves, the outline and the cross-section lines. Wherever possible, several curves should be combined in one drawing.

Cross-section lines should not be drawn through lettering. Lettering should be large and open, drawn with relatively thin lines.

(*Continued on page 722*)

Inert Gas-Shielded Arc Welding Pure Copper*

A.S.M.E. Code Case 934

By John W. Mortimer†

Copper has long been the choice of engineers for corrosion or where high heat transfer are the controlling factors: however, copper has remained one of the most difficult metals to weld. This paper is being presented to propose not only a solution to this problem, but to attempt to explain through a related series of experiments, carried out under shop conditions, that copper can be successfully welded to copper acceptable to the ASME Code.
In addition to this Code, Industry requires a 99% pure copper weld to withstand service corrosion conditions.

The Welding of Copper

STEEL, aluminum, stainless steel, Monel have all yielded to the technique of the welding engineer. Steel welded to steel; aluminum to aluminum; Monel to Monel, etc.; until the welder's rod was tried using copper. Here the usual techniques failed. The welding of copper to copper became a major problem in the research laboratories of the copper and brass companies as well as in the shops and laboratories of fabricating companies supplying coils, pipe and pressure vessels to the oil, food and chemical industries.

Why was there such difficulty with the welding of copper one of the oldest and most abundant metals? In spite of its resistance to welding it remains the first choice for fabricating units where high corrosion and high heat transfer are necessary.

Welding engineers finding no method of using a pure copper weld that would approach the A.S.M.E. standards to a substitute—bronze and silver brazing. This proved acceptable in more than 50% of the cases, but in other cases it was an impractical one. Both bronze and silver corrode at a higher rate under certain conditions than does copper and where the chemical process taking place within the copper unit is highly corrosive the joints which have been brazed are attacked and break down while the copper vessel itself remains intact.

To find the correct technique to produce a pure copper weld became of prime importance and research was begun in July 1946.

This paper is being presented to propose not only a solution to this problem but to attempt to explain through a related series of experiments carried out under shop conditions that copper can be successfully welded to copper with a technique acceptable to the A.S.M.E. code and meeting the requirements of industry.

Case 934 in the A.S.M.E. Unfired Pressure Vessel Code states the physical requirements for copper welding. "The elongation as determined by the free-bend test be not less than 30% for Paragraph U-69‡ and not less than 20% for Paragraph U-70§ construction. Table U-3** values shall be applied for allowable working stress. A minimum tensile strength of 30,000 psi. with joint efficiency of 80% for Paragraph U-69."

In addition to the Code, industry requires a 99% pure copper weld to withstand service corrosive conditions.

These then were the essential requirements which must be met if the problem were to be solved.

The need for copper welding, the economy of copper welding and the future for this type of work is also covered in this report.

Welding Research in Deoxidized Copper

To weld copper with a pure copper weld rod two forces were always confronting the operator, the high heat conductivity of copper and the forming of copper oxides in the molten pool. These forces have prevented the successful welding of pure copper into strong ductile welds because the usual methods of welding did not offer means for their complete control. Copper is second only to silver in heat conductivity which accounts for the difficulty in maintaining the molten pool. Molten copper combines with the oxygen in the surrounding atmosphere so rapidly that the fluxes available did not protect the metal sufficiently to prevent the forming of copper oxides. These oxides not only form gas pockets in the weld but cause embrittlement and greatly reduce the ductility of the metal. The oxyacetylene method of welding copper was able to produce enough heat to control the high heat transfer, but the oxygen in the flame together with the surrounding atmosphere formed more copper oxides then the flux was capable of handling.

The carbon arc method also was successful in controlling the heat transfer and with greater ease than the oxyacetylene process, but carbon was deposited in the weld which resulted in embrittlement.

Further experiments using the metallic arc process produced the same quality welds. The metallic arc was so unstable that the rod coating was unable to shield the arc, and poor control resulted. A second method using the metallic arc with a high preheat of approximately 900° F. and fluxing the plate before welding produced a stronger weld than the previous test but it still lacked ductility. The physical properties of copper have always been improved by cold working the metal, and the remainder of this last test plate was hammered to produce the finer grains necessary to produce this refinement would be impracticable in a pressure vessel with longitudinal seams and girth seams. To gain full control of the welding technique a more perfect flux or rod coating was needed with the metallic arc process.

* Scheduled for Twenty-Ninth Annual Meeting, A.W.S., Philadelphia, Pa., week of Oct. 24, 1948.
† Welding Engineer, The Whitlock Manufacturing Co., Hartford 2, Conn.

‡ U-69, Butt-Welded Joints.
§ U-70, Lap-Welded Joints.
** Table U-3, Material Strength and Allowable Stress Table

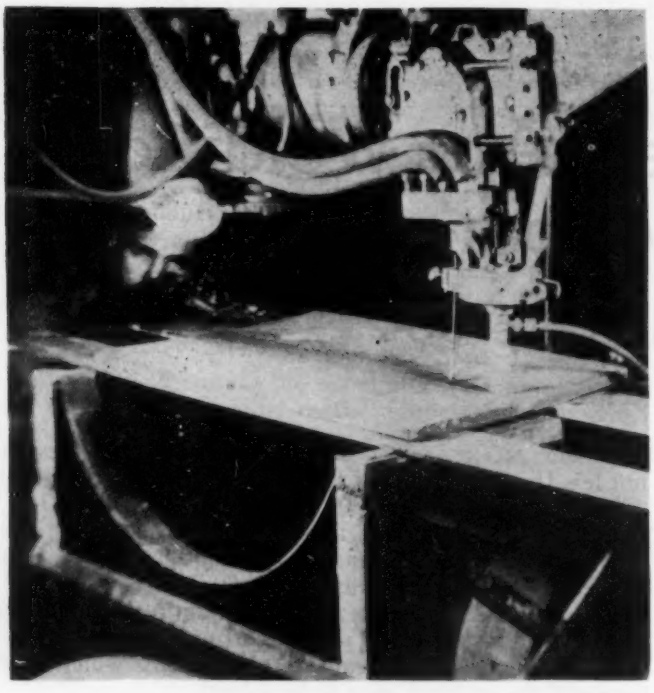


Fig. 1—Welding Copper with Automatic Copper Electrode and Argon Gas Shield

To analyze the function of rod coatings and fluxes, the study of the metallurgy of welding seemed to give the greater promise of solving this problem. No matter what is used for a flux its purpose is to offer a shield to the molten pool from the oxidizing action of the atmosphere around the weld. This shield is usually a gas produced by the coating on the rod and the slag floating on the weld pool. If a gas could protect the pool as the weld rod was added the copper oxides could be controlled. Argon gas will not combine with any known elements and it is commercially produced; therefore, a welding procedure using argon as a shield with the metallic arc process was tried. This proved very difficult for hand welding because of the complex arrangement necessary to feed the gas shield around the arc as the electrode melted off (Fig. 1).

It was solved, however, with the use of automatic equipment. The automatic electrode feed control fed pure copper rod through the head and contact jaws, and argon gas was directed around the electrode at the arc. The test plate was $^3/_8$ in. thick, the electrode $^3/_{16}$ in. in diameter pure copper rod. The action of the arc was violent and very difficult to maintain. When the electrode was fed relatively fast to hold a short arc, freezing resulted. When the electrode was fed slower, a long arc resulted with a violent pool and much splattering. Several different tests were run to gain control of the arc. The angle of the electrode was changed so that the arc had a gouging action on the plate, but the arc was still violent. The angle was reversed to produce a whipping action with the result that the electrode did not freeze but was still uncontrolled. After exhaustive tests on procedure control, using this method of feeding the electrode through an argon gas shield, it was decided to use a tungsten electrode, and feed the pure copper filler rod by hand.

Using tungsten which was not to become part of weld deposit, it was necessary to consider the electrical forces that flow in a welding circuit. When the electrode is deposited in the weld pool, "reverse polarity" is used: that is, the electrode is connected to the positive pole and the plate is connected to the negative pole of the generator. In this circuit the electrons flow from the plate to the electrode causing it to heat and melt off. Using a tungsten electrode the reverse action is required, not to melt off the electrode; therefore, the electrode was connected to the negative pole, and the plate to the positive pole of the generator or "straight polarity."

The tungsten electrode was held in a special holder which was built to allow the argon gas to flow around the electrode and arc (Fig. 2). The base metal was preheated to about 600° F., and this test plate proved better than any produced so far. A second test plate was tried with this same technique, except that a preheat of a dull red of about 1000° F. was used, and the operator had no trouble maintaining control of the arc. The molten pool was smooth and quiet with no evidences of gas pockets while welding. The X-ray test of this plate proved the weld was sound and of good quality. Bend bars and a tensile bar were then cut from the plate with the following results.

Reduced tensile	15,000 psi.
Free bend	Failed 90°
Root bend	Failed 60°

The balance of the test plate was cold worked by hammering. This cold work improved the physical characteristics but the results were not up to code standards. The conclusion drawn from this test was that the inert gas shield with tungsten electrode proved to be the best method for welding copper, but better filler rods were needed.

Metallurgical studies were made to find a copper alloy rod that would produce a 99% pure copper weld deposit. From these studies a few alloying elements were found to improve the copper physical characteristics Silver, tin, manganese and silicon all added different qualities to copper and would combine readily with it.

A 1% silver bearing copper rod is available commercially and this was to be the first step toward improving the weld deposits. The test plate was $^3/_8$ in. thick with a

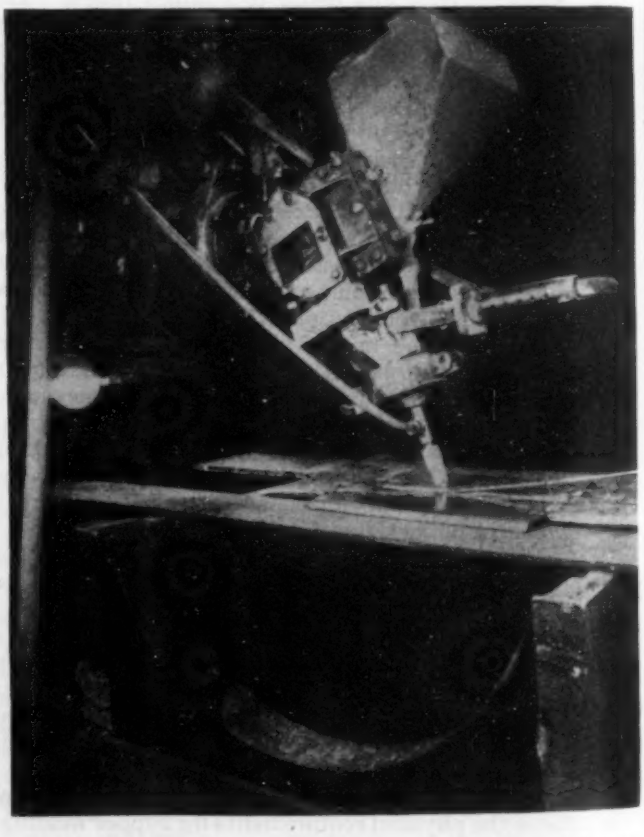


Fig. 2—Welding Copper with Tungsten Electrode and Argon Gas Shield. Copper Filler Metal Added at Angle to Plate

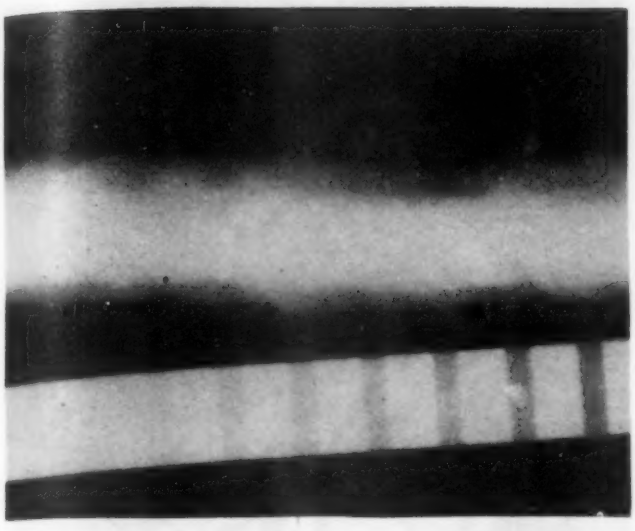


Fig. 3—Radiograph of $^{3}/_{8}$-In. Copper Plate

single bevel of 90° included angle with a back-up strip of copper. The filler rod was $^{3}/_{16}$ in. in diameter which produced the following results:

1. Reduced tensile—20,000 psi. with 6.3% elongation within 4 in.
2. Free bend—180°, 20% elongation with small corner fissures.
3. Nick break—very fine crystal structure.

The balance of this test plate was cold worked by hammering, and tests were made with the following results:

1. Reduced tensile—29,700 psi. with 2.3% elongation within 4 in.
2. Free bend—20.8% elongation with small surface fissures.
3. Nick break—very fine grain with fine dentrites.

This filler metal with 1% silver improved the weldability of the copper and improved the physical characteristics of the metal. A chemical analysis of the weld deposit is as follows: copper, 98.79%; silver, 0.91% and phosphorus, none.

A small amount of impurities in the copper caused a chemical change under the action of the metallic arc which accounts for the 98.79%.

Considering the favorable action silicon and manganese have with copper and the strength gained by a small addition of tin, it was decided to use a filler rod of 99% copper with silicon, tin and manganese. Such a rod is produced commercially. The third test was run using the alloy rod on $^{3}/_{8}$-in. thick plate with a preheat of 1000° F. and the inert gas shield with a tungsten electrode. The performance of this alloy rod was very smooth and quiet under the action of the arc. Current values for this plate were in the range of 350 to 400 amp. with a $^{3}/_{16}$-in. tungsten electrode. The welding groove was machined to a 90°-included angle with a copper

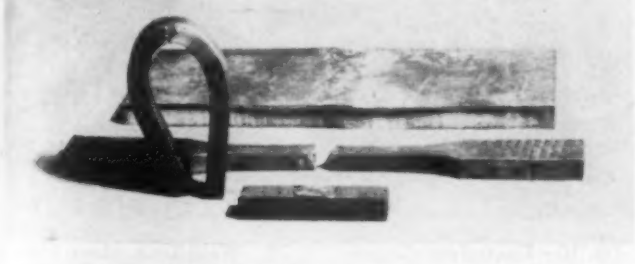


Fig. 4—$^{3}/_{8}$-In. Thick Copper Plate and Test Bars

Fig. 5—Deoxidized Copper Plate. × 75

back-up, and the plate was slightly inclined to keep the molten pool from the front edge of the electrode. The electrode was directed forward to an angle of about 10° resulting in a "Forehand" technique of welding: that is, the arc was pointed in the same direction that the welding progressed. The weld was deposited in one-pass making an overlay of about $^{1}/_{16}$-in. high with no undercuts. When the radiographs were read the weld proved to be sound and clear of all defects (see Fig. 3). Physical test samples were taken from this plate with the following results:

1. Reduced tensile
   (*a*) 30,000 psi. with 26.7% elongation in a 4-in. section.
   (*b*) 30,500 psi. with 35.2% elongation in a 4-in. section.
2. Free bend—32.3% elongation in the outer fibers.
3. Root bend—30.7% elongation in the outer fibers.
4. Face bend in jig—180° with no failure.
5. Nick break—sound weld with no gas pockets.

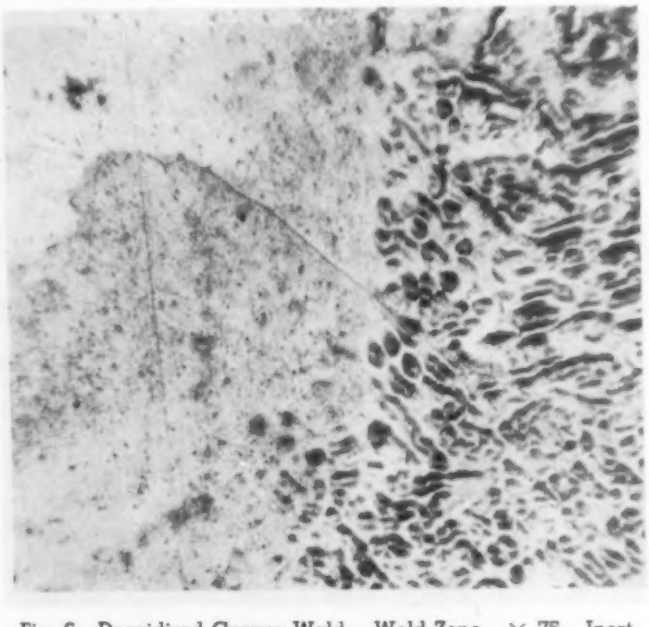


Fig. 6—Deoxidized Copper Weld. Weld Zone. × 75. Inert Gas Shield Procedure. D.-C. Straight Polarity

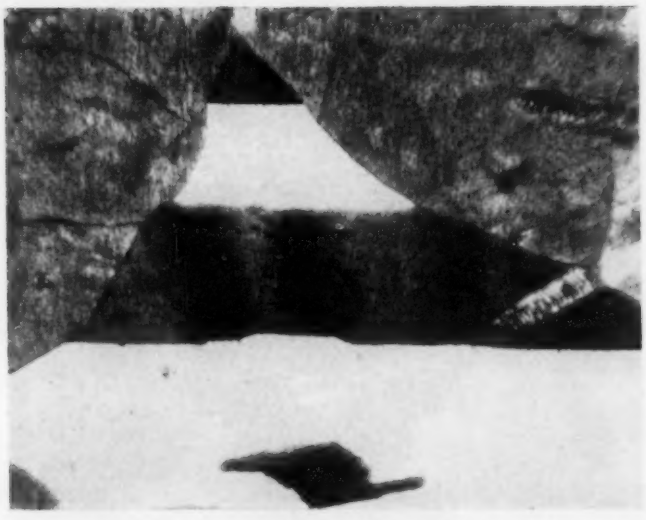


Fig. 7—Deoxidized Copper. Heat Zone of Weld. × 75. Inert Gas Shield Procedure. Rod No. 372. D.-C. Straight Polarity

6. X-ray—radiograph showed sound weld deposit as seen in Fig. 3.
7. Chemical analysis of weld deposit: copper, 99.16% tin, 0.41%, manganese, 0.09% and silicon, 0.10%.

These data show that the code requirements were met as well as the industrial service requirements.

A review of the welding procedure will disclose many techniques common as a whole only to copper. When this research was undertaken, multiple pass welding was naturally tried because of its success in welding other metals. Each test run proved that if the entire weld deposit could be put down in one pass there would be less annealing effect on the underpasses. Also the preheat necessary to weld smooth and sound was in the 1000° F. range; in addition it would be more economical to weld in one pass because less preheat gas would be used. The welding groove had to be a single vee type for two reasons. First, to make the weld in one pass was desired; second, copper upon being heated to the melting point does not have a plastic range. It goes through the critical point from solid to liquid at one temperature; thus, necessitating the use of a back-up strip of copper to support the molten metal at the bottom

Fig. 8—Electrolytic Copper Plate. × 75

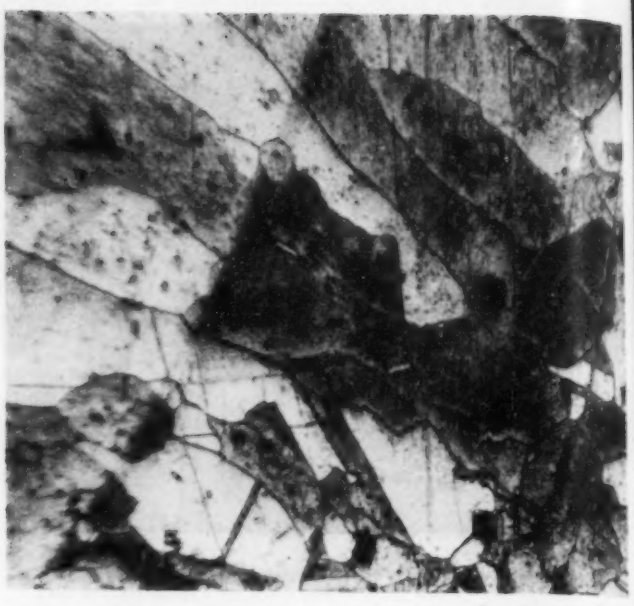


Fig. 9—Electrolytic Copper. × 75. Plate—Heat Zone and Weld. Inert Gas Shield Procedure. Rod No. 372. D.-C. Straight Polarity

of the groove. The shape of the welding groove is controlled by the orifice of the gas shield around the tungsten electrode. On plates up to $^1/_2$ in. thick a single vee groove of 90°-included angle was used. On heavier plates a "U" groove was recommended in order that the electrode may fuse the bottom and minimize the amount of filler rod to be deposited. To keep the puddle from running in front of the electrode the plate was slightly inclined to about 5 to 10° to the horizontal plane. Because of the high preheat, presetting of the plates to allow for warping was not necessary. It may be also stated that with the inert gas-shield process there was a minimum of warping with all the test plates made.

The tungsten electrode was checked very closely for burn-off. The action was much the same as in the atomic hydrogen process, a vaporization took place. This vaporization was found to be controlled by the temperature the electrode was permitted to reach. With preheats of 1000° F. and amperages up in the 400 range, the life of the electrode became a major problem. To

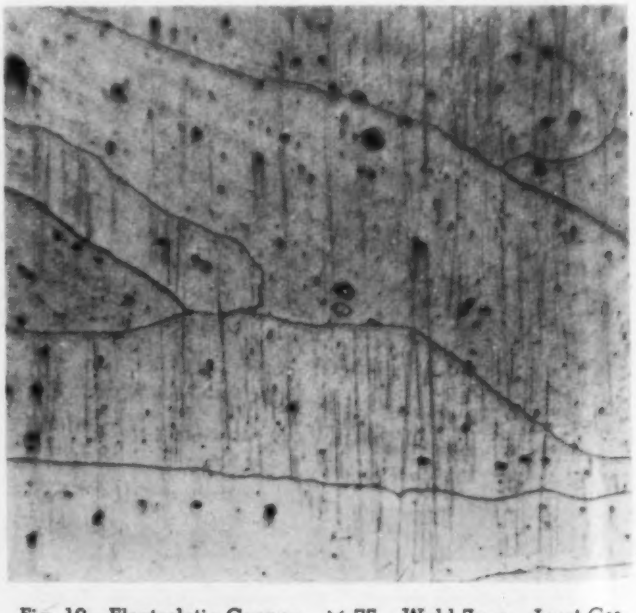


Fig. 10—Electrolytic Copper. × 75. Weld Zone. Inert Gas Shield Procedure. Rod No. 372. D.-C. Straight Polarity

overcome this condition the electrode holder was completely jacketed and water circulated to carry off the heat. Two chucks were used to hold the electrode to assure positive electrical contact. Without the double chuck the heat made a poor contact and further generated heat. The cooling water not only carried the heat away, but also kept the incoming argon gas cool. The cooled gas entering the electrode zone helped to keep the heat down on the metal, and gave a more perfect shield from the gases of the atmosphere. After improving the electrode holder to this point the burn-off was small enough that there was no balling of metal on the tip of the electrode and little vaporization.

When the test plate was completed that gave these excellent results (Figs. 3–7), a procedure was written and experiments were made on copper material from 1/8-in. thick plate up to 5/8-in. thick. All these tests proved satisfactory and the procedure was filed and approved by the A.S.M.E. Unfired Pressure Vessel Code to Case 934.

The following table gives the critical data for this welding procedure as filed with the A.S.M.E. Code.

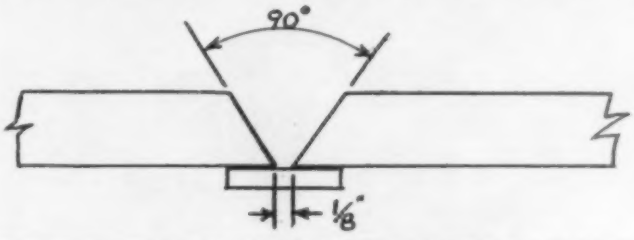


Plate Thickness, In.	Electrode Size, In.	Gas Liters/Min.	Rod Diam., In.	Current, Amp.	Passes
1/8	1/8	6	1/8	200	1
1/4	3/16	7	3/16	300	1
3/8	3/16	7	3/16	350	1
1/2	3/16	8	1/4	400	1
5/8	3/16	8	1/4	400	1

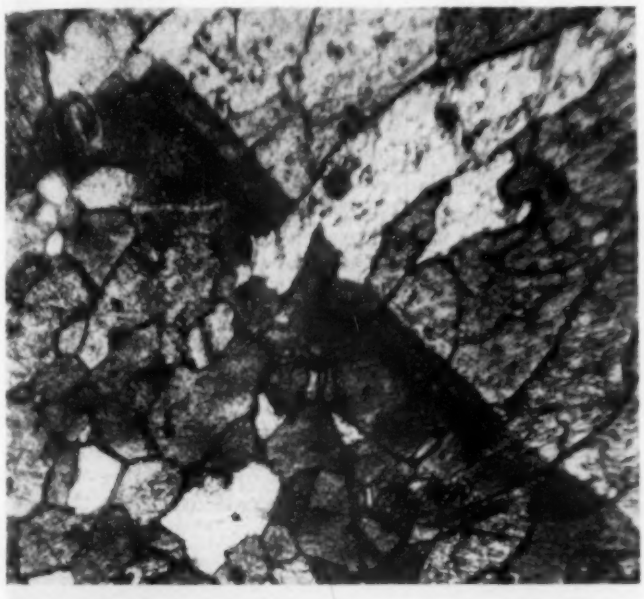


Fig. 11—Electrolytic Copper. × 75. Plate and Heat Zone of Weld. Inert Gas Shield Procedure. Rod. No. 372. A.-C. with High Voltage

Fig. 12—Electrolytic Copper. × 75. Weld Zone. Inert Gas Shield Procedure. Rod No. 372. A.-C. with High Voltage

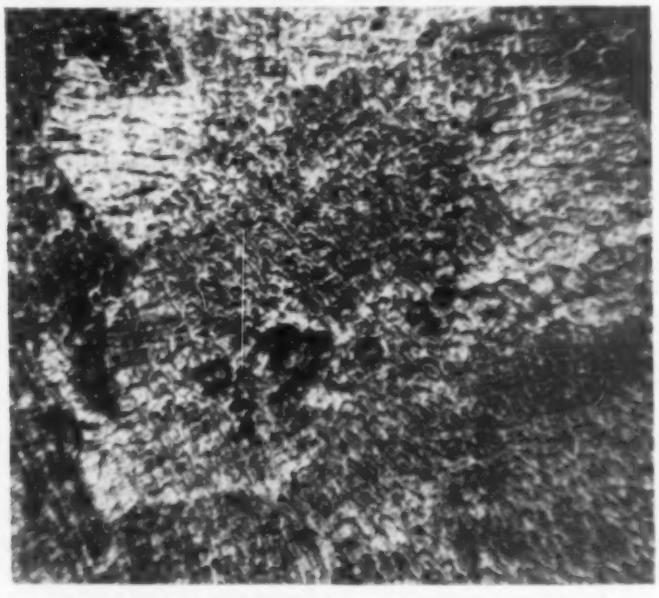


Fig. 13—Electrolytic Copper. × 75. Weld Zone. Inert Gas Shield Procedure. Rod No. 372. A.-C. with High Voltage. Note Lined Up Oxides

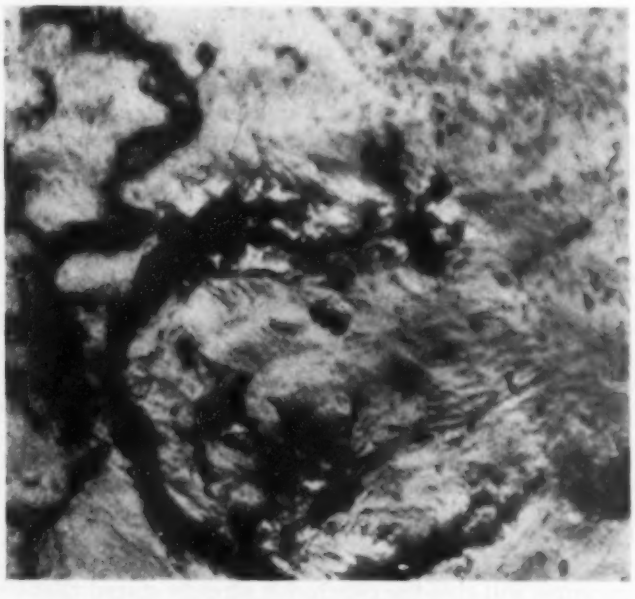


Fig. 14—Electrolytic Copper. × 500. Oxides in Weld Zone

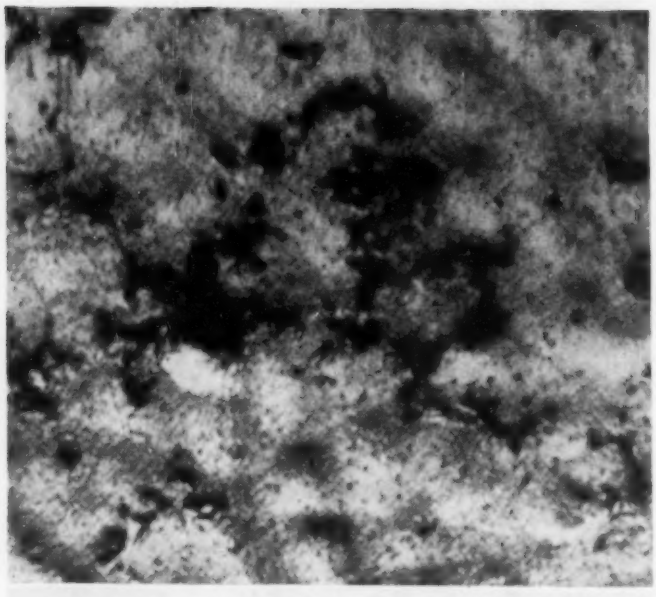


Fig. 15—Electrolytic Copper. × 500. Oxides in Weld Zone

Research in Electrolytic Copper

In handling the engineering of copper vessels, there was always the question of being able to buy the copper and the delivery date. Deoxidized copper was always specified because in the past this was the only type of copper that could be welded to any degree of success. Deoxidized copper is very difficult to purchase in large sheet form, but electrolytic copper is comparatively easy. This raised the question of the weldability of electrolytic copper.

Two tests were made on electrolytic copper plates of $^1/_8$ in. and $^5/_8$ in. thickness. The procedure in welding these plates was exactly the same as on the deoxidized copper so a true comparison could be made. It was found that the welding behaved in a similar fashion to the deoxidized material. Radiographs of the test plates proved the soundness of these welds. The following report is from the actual physical test specimens in the $^5/_8$-in. thick electrolytic plate:

1. Reduced Tensile—30,000 psi. with 36% elongation in 2 in.
2. Free bend—38.3% elongation with no failure.

Several tests were made on electrolytic copper with varying results. The tensile tests usually were up to standard while the bend bars failed in about 50% of the time.

A study of the microstructure disclosed the reason for these failures. Electrolytic copper has copper oxides all through the structure as shown in Fig. 8. These oxides may be large or grouped as shown in Fig. 9. If these large oxides are in the weld vicinity the test bars will fail. Because these oxides are a natural condition in electrolytic copper the welding is not dependable and is therefore not recommended.

Micrographs of weld metal in both electrolytic and deoxidized copper show similar structure which proves that sound weld metal is deposited in both cases. Figures 8 to 13, inclusive, show electrolytic copper as compared to deoxidized copper structures. A study of the structures will give the conclusion already stated that for welding deoxidized copper plate should be used.

Economy in Fabrication

In the fabrication of both copper pipe and copper coils the inert gas-shield method of welding copper has already proved economical as well as time-saving. To further this proof a specific case was used. During the bending of a 6-in. extra heavy copper pipe for a double offset expansion "U" bend the wall cracked in making the final offset bend. This meant replacement of the pipe with a material cost alone of $203.87, and waiting six months for delivery. If permission would be granted to repair this crack by welding, time, money and service would be saved. The insurance company covering this installation approved the inert gas-shield method since that procedure was acceptable to the A.S.M.E. Code.

Before making the repair, drillings were taken around the crack to check the pipe analysis, and prove the material was pure copper (see Fig. 16). The crack was chipped clean and a back-up piece of copper was placed inside the pipe for support. The pipe was welded successfully and tested hydrostatically. Figure 17 shows the repair ground smooth and ready for service. The cost of repairing amounted to $12.50. The only time lost was in correspondence between the insurance company and customer. The saving in dollars amounted to the material cost of replacement minus the repair cost or $191.37 plus the labor already spent in making the bend which amounted to $65.00. This resulted in a total saving of $256.37.

Considering a second example of how this process will prove its economy and lengthen the service life, a copper helical coil made of 3-in. extra heavy deoxidized copper pipe is to be copper welded (see Fig. 18). The comparison of the cost and time element involved in the brazing of the copper coil (the former method of fabricating) and the welding of the same copper coil will demonstrate the economy of this new method of copper welding.

The service conditions are very corrosive and the coils are replaced almost annually. Copper welding was first attempted on this type of coil years ago with the oxy-

Fig. 16—6-In. Copper Pipe Showing Crack and Drill Marks

Fig. 17—6-In. XH Copper Pipe Repaired

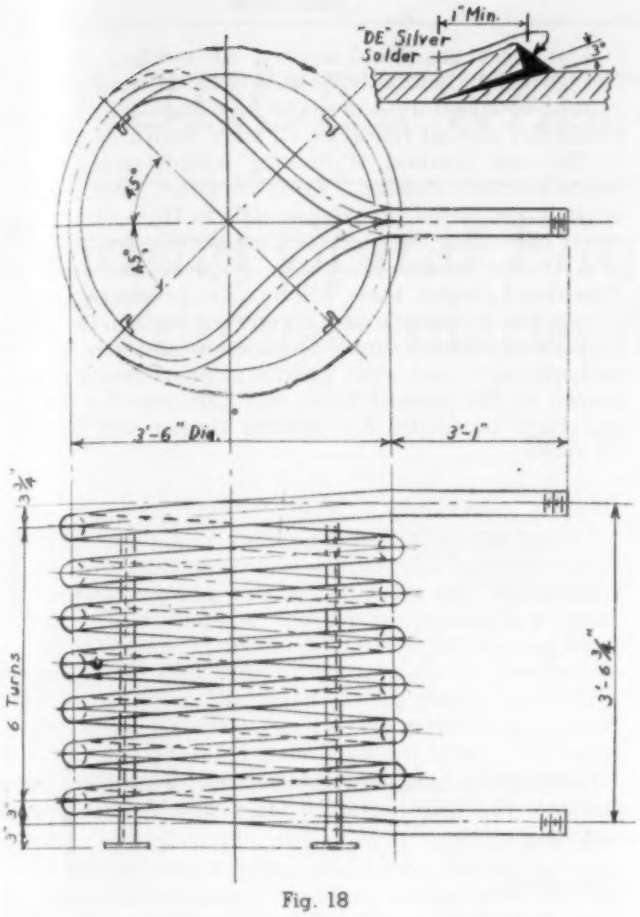
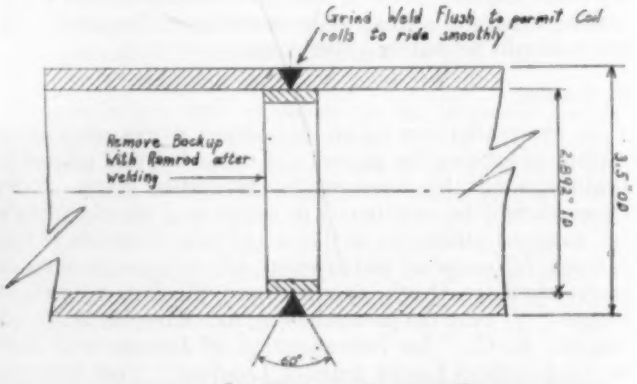


Fig. 18



3" XH Copper Seamless Pipe

Fig. 19

acetylene and carbon arc process, but both failed on hydrostatic testing and physical weld test specimens. Silver brazing was acceptable to service with a $^1/_2$-in. thick lead coating for 6-in. on each side of the joint to protect the silver from corrosion. Sketch 1 shows a sketch of the complete coil with a detail of the silver braze joint. This coil was made by driving the pipe through a set of pyramid rolls. With the silver braze joint it was impossible to do this because of the flare on the outside diameter of the pipe; therefore, these joints were brazed in the assembled position which was costly as well as difficult.

Using the welding technique it is possible to weld the straight pipes and then coil. Figure 19 shows the joint used for this process. Shop records show the silver brazed joints required $7^1/_2$ hr. and the copper welds required less than 1 hr. To coil the pipe for silver brazing took 8 hr., and to coil continuously after welding takes $4^1/_2$ hr. The following table shows the comparison of these labor figures:

	Silver Braze, Hr.	Copper Weld, Hr.
Silver joints	52.5	7
Coiling	8.0	4.5
Total	60.5	11.5
	11.5	
Saved	49.0	

This results in a saving of 81% of time, and a direct economy in dollars and labor. The customer also saves in that no lead covering is needed to protect the joint. The life of the coil would also be lengthened because of the copper used throughout.

Table 1—Shell Comparative Costs

Size: 42 x 120 x $^1/_4$ In. Thick

Material Type	Material Cost	Procedure Costs L&O and Profit	Selling Price
Steel	$ 110	$197	$ 307
Steel copper lined	400	837	1237
Copper	770	630	1400
Stainless			
Type 304	890	685	1575
Type 316	1220	680	1900
Type 347	1070	680	1750
Silicon-bronze	845	635	1480
Monel	1050	650	1700

A third example of the economy and service to which this process may be applied is in the manufacturing of pressure vessels using pure copper plate (Fig. 20). The practice in the past has been to use silicon-bronze or stainless steel when copper was the natural material for the service condition. The basic cost of silicon-bronze or stainless steel or copper plate varies slightly, but the life of the vessel in service may be unlimited with copper plate.

To compare the actual cost of pressure vessels made of different metals the following table was drawn up from production figures. The table shows the comparative selling price of the same size vessel.

From this table certain pertinent facts are brought out. Steel shells

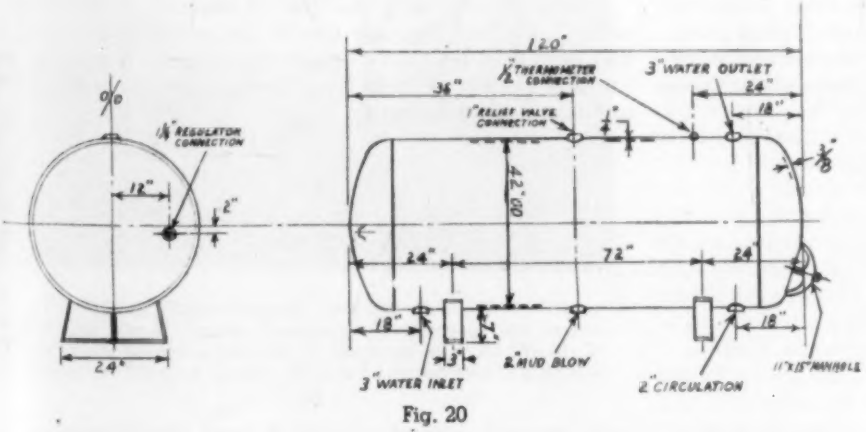


Fig. 20

are the most economical to build from both the cost of material and fabricating cost. Steel shells with copper lining offer good characteristics and are next to steel in cost. One fact from service maintenance that the table does not show, however, is the servicing of these units which has been necessary in some cases. The servicing was necessary because of leaks that developed in the liner. Copper compares favorably with copper lined steel, and the table shows that in comparison with the other corrosion resisting metals it is the most economical.

Of the many applications at the present time for this new technique of welding copper is the possibility of prefabricating sections of copper piping welded in the shop and sent to the field for erection, a method similar to the one used for alloy steel pipe. This method assures good welds and preliminary testing before erection.

Conclusion

The inert gas-shield method of welding deoxidized copper will undoubtedly be used in field operations which cannot now be foreseen. The food industries, chemical industries and oil refineries all have shown deep interest in the new method of making sound, strong, ductile welds to Code standards using copper. There has been enough completed pressure vessels in these industries to prove how much the need is for copper construction.

With the present knowledge of procedure control for deoxidized copper, there will be more production making it possible to improve and lower even further the present cost of manufacturing. Experience and research will undoubtedly make even greater improvements than are known at the present time, and new uses for the inert gas-shield procedure for welding copper will be found.

(*Continued from page 714*)

What a Paper Should Contain

In general, a good paper will be organized as follows:

1. Title
2. Introductory summary
3. Body
4. Appendixes (if necessary)
5. References (if necessary)

Title

Good titles interest the readers. Titles should consist of the *minimum* number of words necessary to indicate accurately the subject of the paper and to make possible accurate indexing. Frequently the best title can be chosen after the manuscript is complete.

Introductory Summary

A *concise* digest of the *substance* of a paper should be given in an introductory summary, from which the reader can get a clear understanding of what is in the paper. The summary should *not* describe the *paper* nor give excerpts from it, but should give a definite idea of its scope, method of approach and important conclusions.

Body

In general, a clear statement of the problem, an outline of the author's approach and a summary of results should make up the body of the paper. Subheadings should be used to divide the paper into its important, logical parts. Development should proceed in logical, connected order. Often the results can be shown best by curves, charts or tables.

Pictures and tables should illustrate or supplement, *not duplicate* the text matter. They should not duplicate each other.

Appendixes

All extended mathematical treatments should be placed in appendixes with only references in the text. Detailed explanations of methods should be omitted unless necessary to a clear understanding of the paper; then they should be put in appendixes.

References

So the reader can locate important works used by the author in writing the paper, and other helpful, related literature, a suitable reference list should be given. References should be numbered in order and should include: (*a*) name of author or authors, (*b*) title of article in quotations, (*c*) name of publication, (*d*) volume number, (*e*) page numbers (both opening and closing, to indicate length), (*f*) year (in parentheses), as: Krefeld, W. J., and Ingalls, E. C., "An Investigation of Beams with Butt-Welded Splices Under Impact Loading," THE WELDING JOURNAL, **26** (7), Research Suppl., 372-s to 400-s (1947). No reference should be made to unpublished material.

Acknowledgments

Credit should be given for all matter obtained from other authors. Specific credit for a thought or device mentioned in text may be given in text. In general, acknowledgments of help by associates or others should be made in a brief footnote.

Welding Spiral Flights with Automatic Tractor Inside 4-Ft. Diam. Kiln

By J. W. Hill*

THE welding of the spiral flights on the inside of rotary kilns or coolers with regular open arc hand techniques is a difficult, tedious and uncomfortable job. By engineering a setup for driving a tractor-mounted Lincolnweld automatic hidden arc welding head through a 4-ft. diameter cooler, the C. O. Bartlett & Snow Co., at their Cleveland, Ohio, plant, were able, after the proper fixtures and procedures had been worked out, to deposit 100 ft. of weld bead per hour. By welding with automatic head a considerable saving was obtained over hand welding due to three factors:

1. The cramped and unfavorable conditions under which hand welding would have had to be done.
2. Even with the additional men needed to service the automatic head in this unusual position the feet of weld per man hour was higher than hand under normal conditions.
3. The total elapsed time that the job was on the floor was greatly reduced thus permitting the floor to be open for following jobs much sooner.

The type rotary kiln on which this technique is used is illustrated in Fig. 1. This particular kiln is 115 ft. 5 in. long, made up of three flanged shell sections that are bolted together. The three shells are each made by butt welding four half-sections both longitudinally and circumferentially. The plate used is $\frac{1}{4}$-in. thick and the plain butt welds are made with the hidden arc process, using a $\frac{7}{32}$-in. diam. wire, 700 amp. and a travel speed of 30 in. per minute.

Fig. 1—One of Three Flanged Sections of a 115-Ft. Rotary Cooler for the Chemical Industry. Welding of the Inside Spiral Flight Involves 3200 Ft. of Continuous Weld Which Is Deposited by Using a Tractor-Mounted Lincolnweld Automatic Head

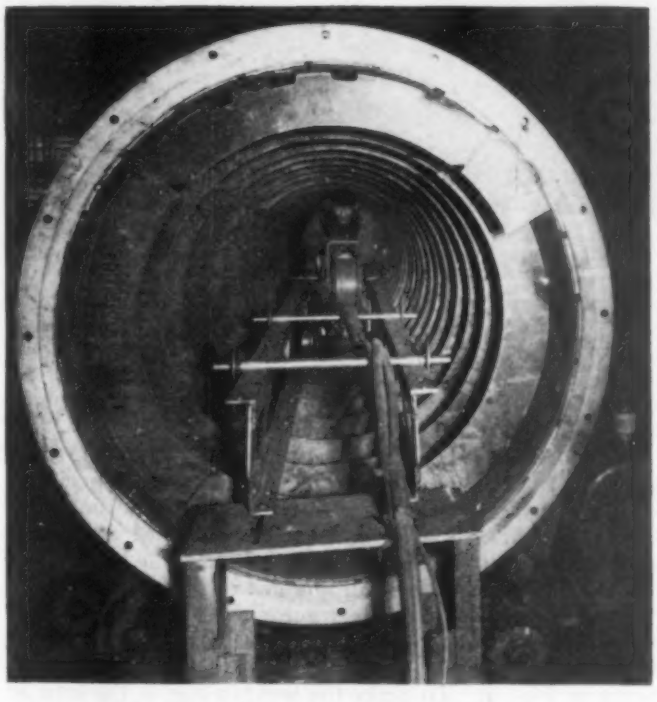


Fig. 2—The End of the Cooler During Welding Operations Shows the Setup Engineered by the C. O. Bartlett & Snow Co., Cleveland Plant. Tracks Are Mounted in the Shell Level with the Floor. Rotation and Forward Motion Are Coordinated by Allowing the Thrust of the 1-Ft. Lead on the Flight to Propel the Tractor

On the inside of the shells, specifications call for a flight five inches high, $\frac{5}{8}$-in. thick with a 1-ft. lead. The weld joining the flight to the shell must be continuous on each side.

Because of the large amount of welding called for on this flight, the possibility of depositing it automatically is immediately suggested. The small diameter of the cooler and 1-ft. pitch of the flight, however, eliminate placing a tractor mounted head sideways in the shell and making the fillet welds by rotating the kiln under the tractor. The other possibility, driving the tractor longitudinally through the kiln, necessitates coordinating the rotation of the kiln with the forward travel of the tractor. This problem is solved by disconnecting the drive motor on the tractor and utilizing the forward lead on the flight to provide the thrust to propel the tractor.

A track approximately 45 ft. long, made by welding angles as shown in Fig. 2, is mounted through the kiln. The top rails are used for carrying the rollers over which the welding cables are strung to the head. As the weld-

* Plant Superintendent, The C. O. Bartlett & Snow Co., Cleveland, Ohio.

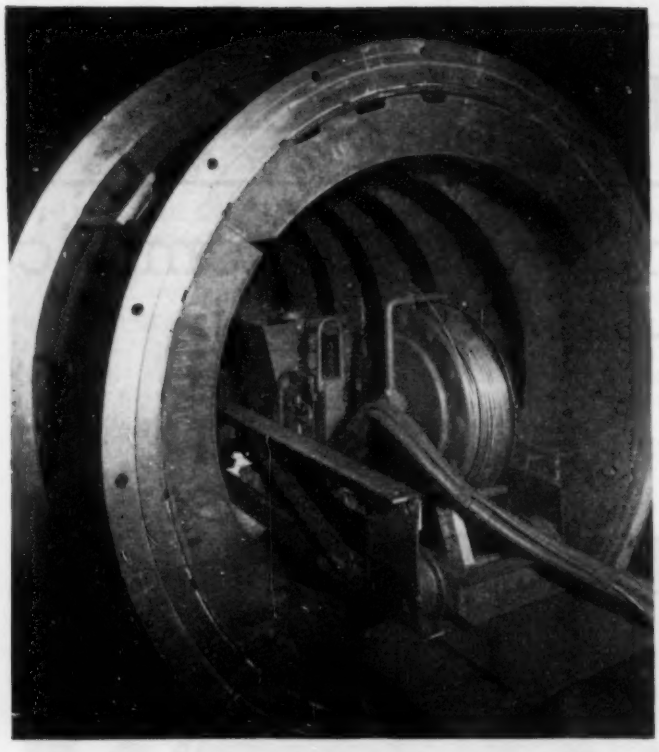


Fig. 3—Tractor Emerging from the Shell as Weld Is Completed. Weld That Has Just Been Made Is Seen Directly Above the Automatic Head. Rotation for This Weld Is Counterclockwise

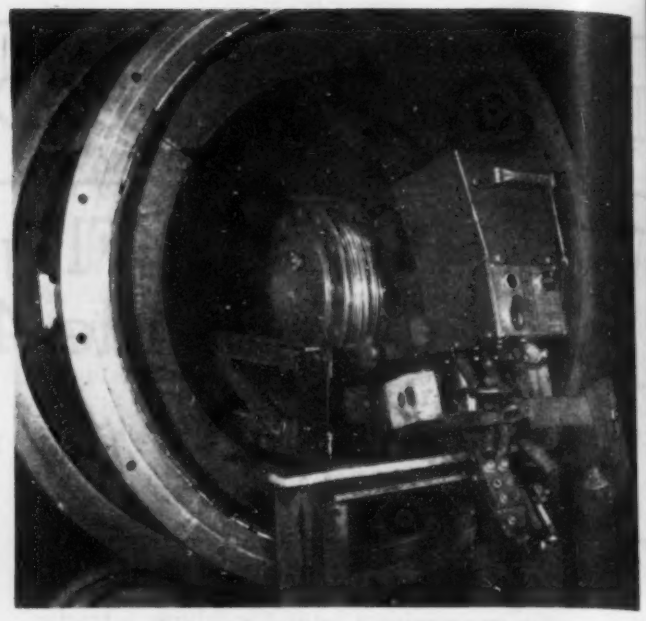


Fig. 4—Tractor Is Shown Here in Position to Make Weld on the Other Side of the Flight. Rotation of Shell Will Be Clockwise. Figure Also Shows the Special Drive Rollers Added to the Tractor Head to Transfer Thrust of the Flight to the Tractor. Standard, Rubber-Tired Wheels Are Replaced with Flanged Wheels and Wooden Blocks

ing progresses through the kiln, a helper pulls the cables out ahead of the tractor. The bottom set of rails carries the tractor. Adjustment tables are placed at each end of the track to permit leveling of the rails.

The standard head is removed from its standard, rubber-tired tractor mounting and placed in an especially constructed tractor dolly. One pair of wheels of the dolly is flanged while directly underneath the head a pair of wooden blocks is used in place of wheels. The blocks are necessary to afford a certain amount of resistance to the forward motion so that the tractor does not run ahead and pull away from the joint. The tractor, mounted on the rails as it finishes welding one side of the flight, is shown in Fig. 3. To make the weld in Fig. 3, the kiln is rotated counterclockwise. The weld is being made on the side of the flight toward the end of the kiln shown.

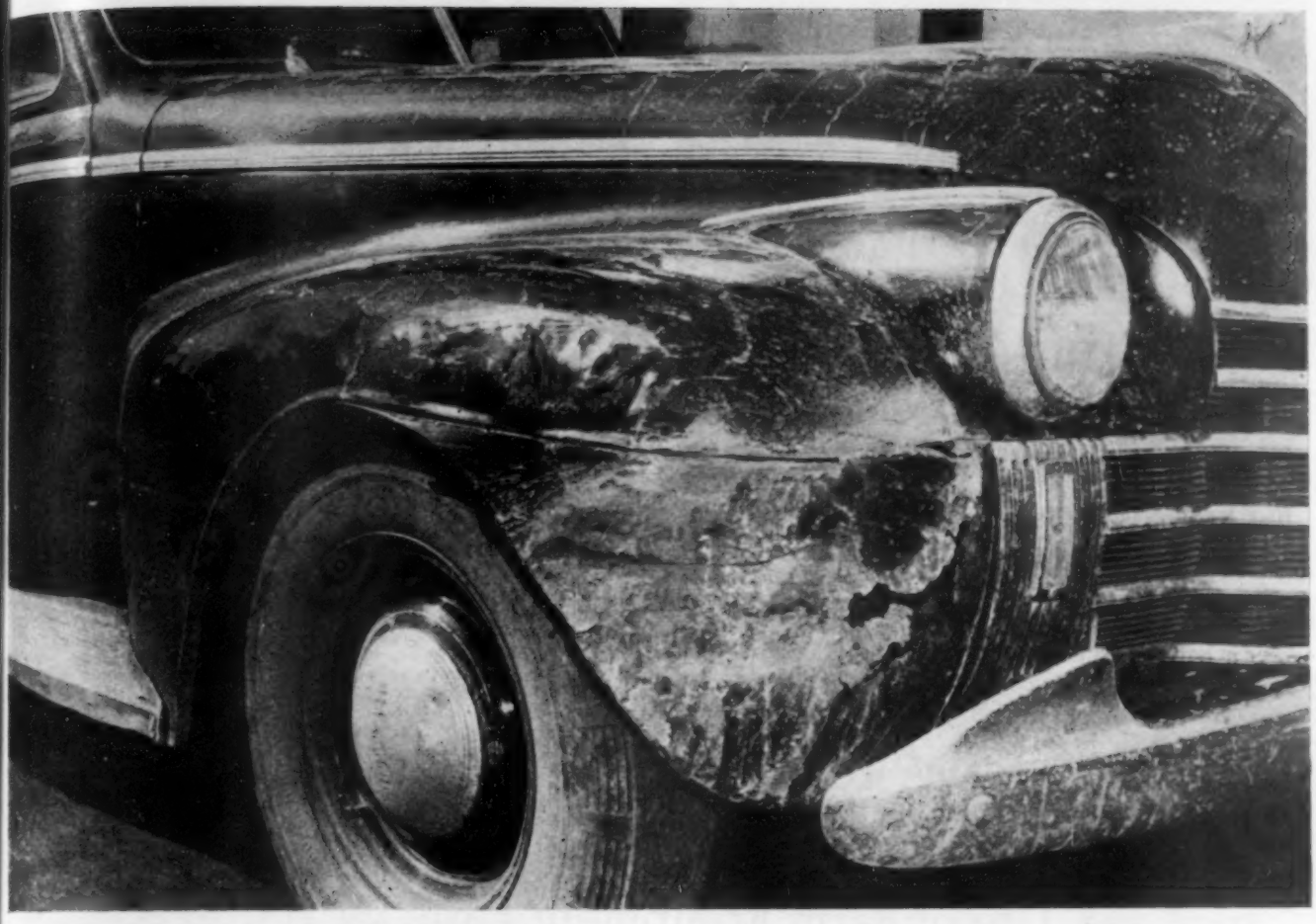
The forward motion of the tractor is supplied by the rotation of the kiln and the forward lead on the flight. The force is a pushing rather than a pulling force, and the arrangement of guides on the head to secure this force is shown in Fig. 4. The push thrust of the lead on the flight is transferred to the tractor through two small rollers on the head which ride on the shell and flight immediately ahead of the electrode. The wheels are set at 90° so that they also keep the electrode centered in the fillet joint. A larger wheel is arranged to ride on the opposite side of the flight from the weld. The large wheel is set ahead of the smaller wheels on the leading side of the flight so that a clamping effect is achieved. Still another wheel, set to ride against the side rail of the track, prevents the side thrust from giving the tractor any sideway movement.

The drive motor on the shell rolling fixture is relayed with the welding circuit so that the operator inside the kiln can start the operation. The weld is made at a travel speed of 30 in. per minute using 550 amp. with 30 v and $^{5}/_{32}$ wire. The flight is welded on both sides. The granular flux used in the hidden arc-welding process is not fed through the regular hopper. A pile of flux is placed in the bottom of the shell on both sides of the flight being welded. As the welding progresses the screw action of the flight keeps feeding the flux ahead. The operator has only to occasionally brush the flux down as it attempts to climb up the side of the shell. Having the flux on both sides of the flight prevents burn-through where the fit-up between the flight and the shell is poor.

Editorial Note

Practical Short Articles for This Section Are Urgently Needed

—W. Spraragen, Editor



Here's a Fender That Was Reduced to Rust Scale Below the Beading. After Careful Examination, the Body Man Decided to Cut Out the Rusted Metal and Put in a Patch

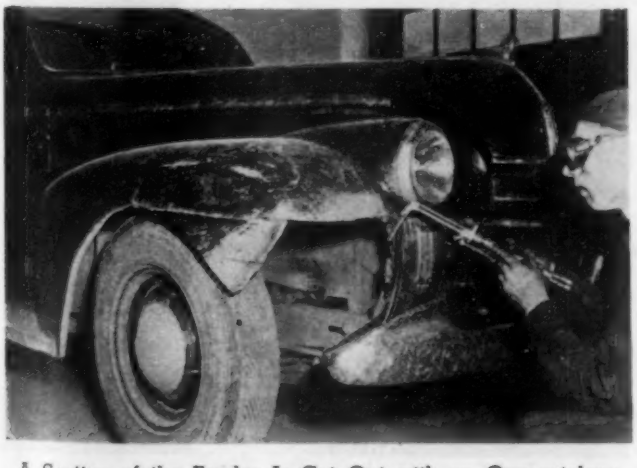
You Can Make Rusted Fenders Good as New

Welding and Cutting Helps Complete a Tough Job

By F. C. Geibig*

WHAT do you do when a rusted fender job comes into the shop? One body shop makes good use of its oxyacetylene equipment, as shown in the illustrations, and turns out a fender as good as new. Using his cutting attachment, the body man cuts out the rusted section and then cuts a patch from an old fender. Then, with his welding blowpipe he heats and shapes the patch to a perfect fit and welds it in place. The weld is ground smooth and the fender repainted.

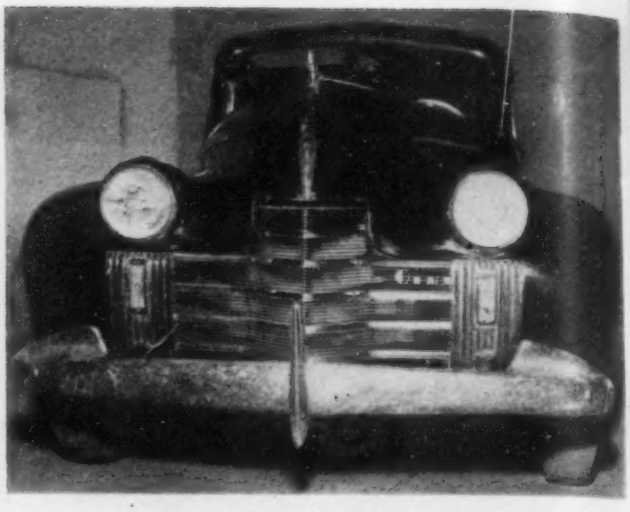
* The Linde Air Products Co., Newark, N. J.



A Section of the Fender Is Cut Out with an Oxyacetylene Blowpipe. The Operator Keeps the Flame Away from the Chrome. A Guard (Not Shown) Is Placed Between the Fender and Wheel to Protect the Tire from Heat

With His Cutting Attachment the Operator Cuts a Metal Patch from an Old Fender. Then the Operator Heats and Shapes the Patch. Time Spent in Getting a Perfect Fit Assures a Better Finished Job

Here the Operator Is Welding the Patch. He Has Already Tack Welded It in Place. Careful Attention to Flame Control and Blowpipe Manipulation Pays Off with a Strong Weld and No Metal Burn



(Photographs: Courtesy of Duco-Dulux Refinisher)

You Can't Tell the Difference Between the Repaired Fender and the Original. After Expert Grinding, Sanding and a Light Solder "Wash," Some Fine Forming Work Was Done Along the Bead Line. After Hand Sanding, It Is Painted and Polished

The result is a strong, good-looking fender. The car owner is happy and the shop builds a profitable business.

How to Make Them Last

By J. E. Dato*

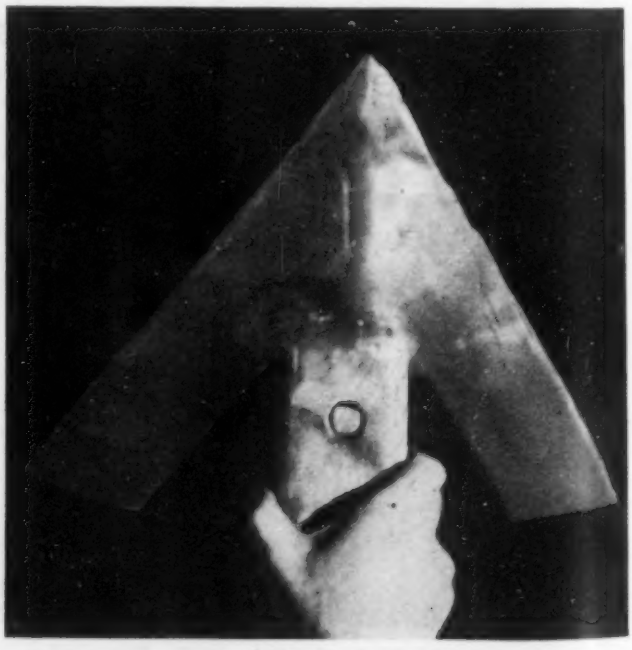
Increase Life of Farm Equipment Parts by Hard-Facing

WHEN YOU hard-face equipment, such as plow shares and corn planter runners, they last more than twice as long as untreated parts. This will save money, time and bother for the farmer.

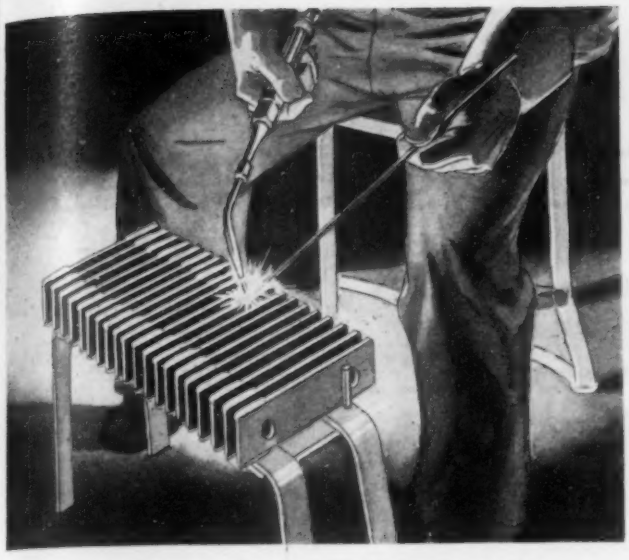
Hard-facing can be a profitable business for your shop. By developing a hard-facing business you can help take up the slack of those slow seasons. Here are some pieces of farm equipment that have been hard-faced. Tell the farmers in your district about these jobs and watch your business grow

* The Linde Air Products Co., Kansas City, Mo.

These Cylinder Thresher Teeth Have Threshed Wheat from 1200 Acres. Notice the Tooth on the Right. It Was Hard-Faced and Is Hardly Worn

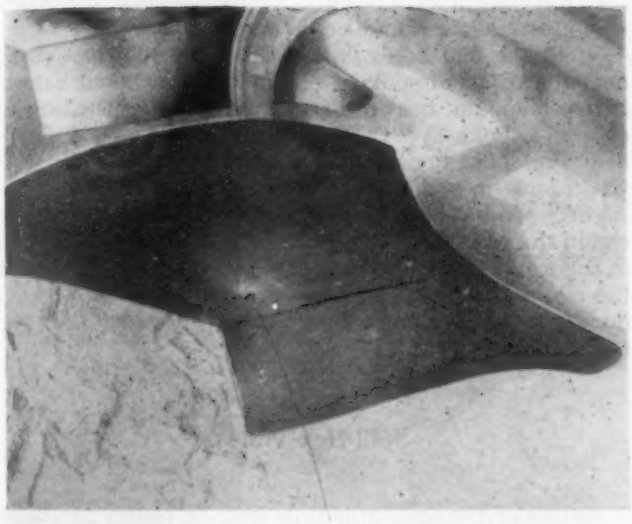


The Secret of Long Life for This Plow Sweep Is a Deposit of Haynes Stellite Rod Along the Cutting Edge. It's Still Good After Plowing 900 Acres



With This Jig You Can Hard-Face 500 Feed Mill Hammers a Day

You Can Make Corn Planter Runners Self-Sharpening by Hard-Facing Them on One Side. Runners That Are Hard-Faced Stay Sharp Longer Than Plain Steel Runners



Still in Good Condition After Plowing 42 Acres in Severely Abrasive Soil. This 14-In. Plow Share Was Hard-Faced with Haystellite Tube Rod

(Right) Drilling Water Wells Is Hard on Tools. This Fishtail Bit Lasted Much Longer Before Resharpening Because It Was Hard-Faced

Bound Volume 1947 Welding Journal

A few copies of the bound volume of The Welding Journal for the year 1947 are still available. Price $12.50. This volume consists of 1164 pages of The Welding Journal and 752 pages of the Research Supplement, a total of 1916 pages. The volume contains a Subject and Authors Index and represents a veritable encyclopedia of information on every phase of welding. The research section represents nearly a million dollars worth of research. The Journals are bound in attractive imitation black leather covers. Orders may be placed with the American Welding Society, 33 West 39th Street, New York 18, N. Y.

It's Easy to Weld Pulleys and Gears

By F. F. Mooney*

This Article Tells You How to Use Your Blowpipe for Preheat

WHEN welding shops or plant maintenance crews repair broken cast-iron pulleys and gears, expansion and contraction stresses are usually controlled by preheating the entire casting. In emergencies or when the casting is too big, a preheating furnace may not be practical. Here are some suggestions on how you can bronze weld or fusion weld breaks in these castings by using your blowpipe flame for preheat. Bronze welding is usually recommended because less heat is required than for fusion welding. Less heat produces less expansion.

One Spoke Broken

When a single spoke is broken near the solid hub of a pulley, as shown in Fig. 1, the procedure for controlling stresses is simple. First vee the break from both sides. Then heat the entire gear with the blowpipe flame. It should be just warm enough so you can't hold your bare hand on the gear. Then heat the spoke on each side of the broken spoke slightly more than the rest. The rim section within the three spokes should also be heated a little more. At the same time, gradually heat the area at the break until it reaches bronze-welding heat. In this way you can make the weld quickly without losing the preheat applied to the adjacent spokes.

When the weld is completed, the adjacent spokes and rim section should be reheated slightly until the weld has begun to cool. Keep the entire part covered to avoid drafts and rapid cooling.

* The Linde Air Products Co., Philadelphia, Pa.

Several Breaks

When there are breaks in the rim and spokes, as shown in Fig. 2, the order of welding is important. After you vee the breaks properly, make spoke welds "A" and "B" in that order. Do not attempt weld "B" until weld "A" has completely cooled. Apply the preheat the same as you would for a break in a single spoke.

Weld the rim break last. With the blowpipe flame, heat the adjacent spokes. If the break is about halfway between spokes, heat both spokes alike. If the break is close to a spoke, give that spoke more heat. Also slightly heat the spokes on each side of the one near the weld. Use a jack or wedge bar to help keep the fractured ends slightly separated. Do not apply too much heat to the rim in the vicinity of the break or you will create pressure in the weld. The heating of spokes, plus a slight heat in the rim section, plus some form of jacking will help you maintain pitch dimensions. Again, avoid drafts and rapid cooling.

Split-Hub Pulleys

Spokes of the split-hub type gear or pulley can be repaired easily, too. Prepare the fracture in the usual way. Then clamp a stub shaft of the correct diameter in the hub. This will prevent distortion of the hub. Then carry out the rest of the operation as you would for a single spoke break as shown for Fig. 1.

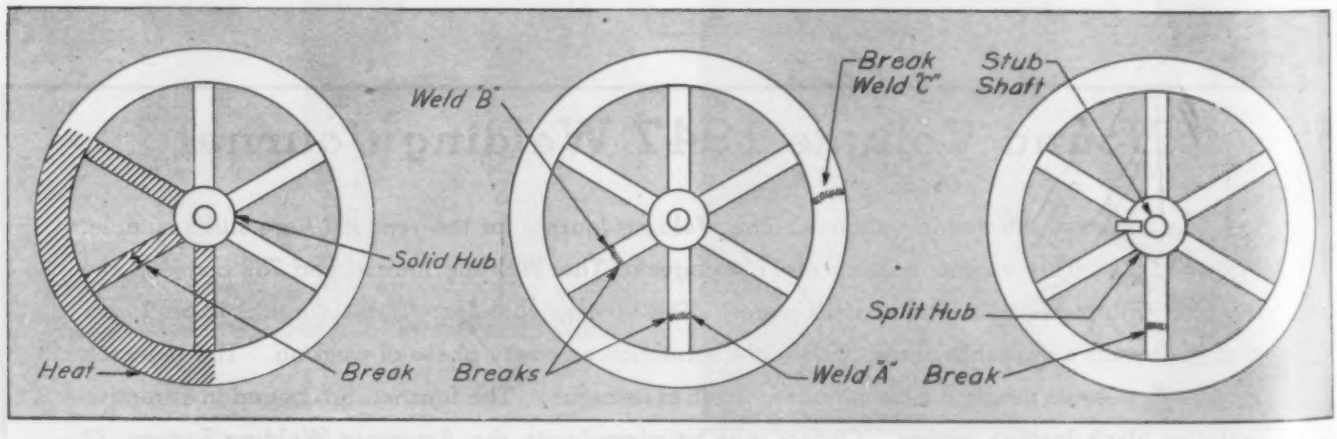


Fig. 1—When a Single Spoke is Fractured Near the Hub, Heat the Adjacent Spokes and Rim Section. Keep Even Heat in the Broken Spoke and Complete the Weld

Fig. 2—When There Are Breaks in Two Spokes and the Rim, Welds Are Made in the Order *A, B, C.* Use a Wedge Bar or Jack to Maintain Pitch Dimensions

Fig. 3—Before Welding Spokes of the Split-Hub Type Gear or Pulley, Clamp a Stub Shaft of the Correct Diameter in the Hub. Then Proceed as in Fig. 1

Fig. 1—View of the Road Bridge to the Rupperswil-Auenstein Hydroelectric Plant

The total span is 273 ft. The roadway is 10½ ft. wide. The bridge was constructed in the shop in sections 110, 62 and 103 ft. long. Staging was erected in the water to permit erection.

The Road Bridge to the Rupperswil-Auenstein Hydroelectric Plant in Switzerland*

By A. Lumbotte

* Translation of "Pont-Route D'Accès À L'Usine Hydro-Electrique de Rupperswil-Auenstein (Suisse)" published in *Ossature Métallique*, 13 (3) 126-128 (March 1948), by Dr. G. E. Claussen, Chief Metallurgist, Reid-Avery Co.

THE Rupperswil-Auenstein hydroelectric plant on the Aar River is equipped with two sets of 23,000-kva. generators driven by Kaplan turbines. One set generates single-phase current (16⅔ cycles) for the state railways. The other generates three-phase (50 cycles) for the motive power of the Northeast. Construction was begun in March 1942 and the plant was put in service in the autumn of 1945. The lake behind the dam is 4½ miles long, has a surface area of 4.4 square miles and provides an average of 10,400 cu. ft. per second.

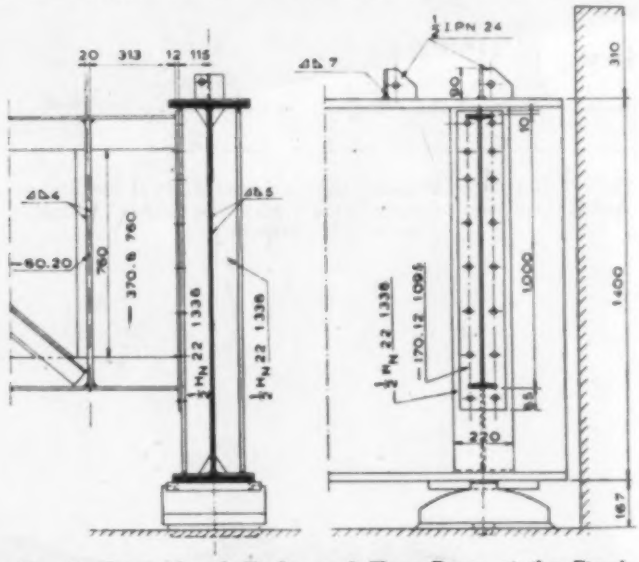


Fig. 3—Assembly of Girder and Floor Beam at the Fixed Support. Note the Extensive Use of Wide Flange Sections Cut and Assembled by Welding. Dimensions in Millimeters

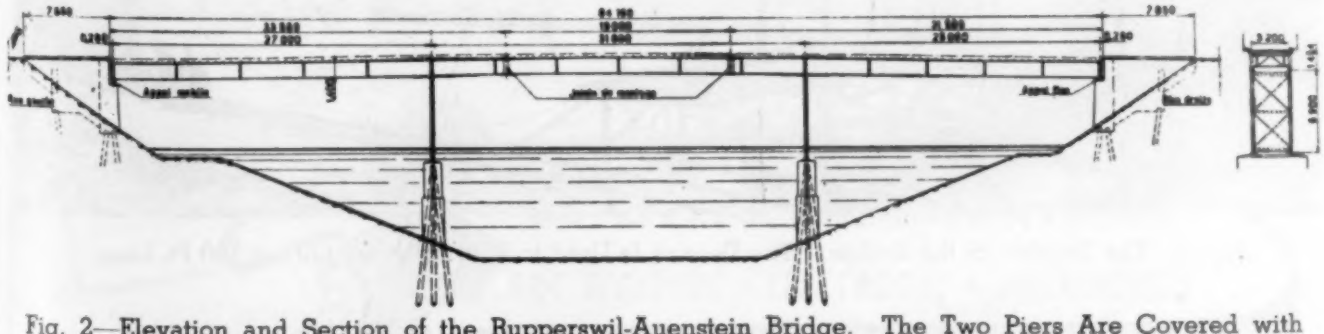


Fig. 2—Elevation and Section of the Rupperswil-Auenstein Bridge. The Two Piers Are Covered with Concrete and Serve as Free, Elastic Supports. Dimensions in Meters

Appui Fixe, fixed support; Appui Mobile, free support; Rive gauche, Rive droite, left bank, right bank; Joints de Montage, field joints.

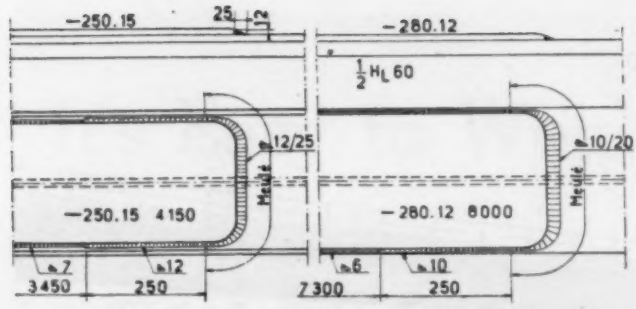


Fig. 4—Welding Details at the Ends of Cover Plates. These Plates Have Been Carefully Rounded at Their Junction with the Girder. Dimensions in Millimeters

Coupe, section; Vue en plan, top view; Meule, ground.

It was necessary to transport machinery to the plant by road. Consequently, a road was built off the main continental road to the west from Rupperswil. The road is 14.7 feet wide and crosses the canal and the Aar River by means of two steel plate girder bridges with reinforced concrete piers. The roadway on the bridge is only $10^1/_2$ ft. wide with two sidewalks 2.1 ft. wide.

The canal bridge was built by Wartmann & Co. of Brugg (Argovie) and is a few hundred feet from the plant. The total span of the bridge is 273 ft. in three sections: 88, 103 and 82 ft. The bridge was designed on the basis of the state ordinance, dated May 14, 1935, concerning design and construction of steel structures.

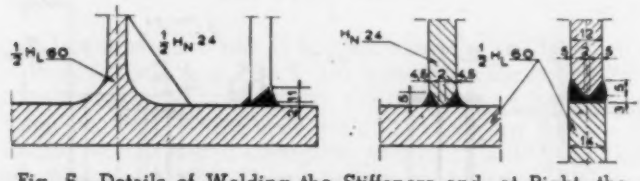


Fig. 5—Details of Welding the Stiffeners and, at Right, the Assembly of Minor Details to the Web of the Girder. Dimensions in Millimeters

The girders of the bridge are 4.6 ft. high and are made of two split H sections and a web plate 31.4 x 0.47 in. thick. The girders are in three lengths: 110, 62 and 103 ft. All welding was done in the shop and the girders were transported by road to the site. The floor beams also were shop welded and were attached by riveting. The wind bracing also was riveted. Figures 3 to 5 show some of the details of shop assembly.

The bridge weighs about 355 tons or 4.2 tons per meter. Of this, 1.1 ton is steel, 3.1 tons is reinforced concrete and asphalt.

The bridge can carry a tractor with trailer at a speed of 3.1 miles per hour loaded, for example, with a Kaplan wheel weighing 40 tons.

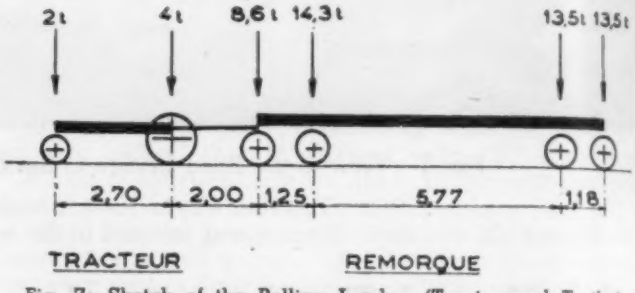


Fig. 7—Sketch of the Rolling Loads. (Tractor and Trailer) Loads in Tons. Dimensions in Meters

This type of bridge is rather specialized. The sections of girders are over 98 ft. long, are completely shop welded, were transported to the site by road and were assembled in the field by riveting. This bridge provides safe passage of very heavy machinery to the power station.

Fig. 6—The Erection of the Bridge. The Derrick Is Used to Put in Place a Girder 100 Ft. Long

Conventional welder circuit (left) shows irregular current flow, arc "black-outs," and unbalance (d-c component) in the alternations above and below the straight zero line.

The built-in stability of G-E Type WP Inert-Arc welders produces the uniform "balanced-wave" current (right below).

Originally designed *specifically* for welding aluminum without flux and with minimized radio interference, these Type WP Inert-Arc welders have been made even better than ever with the incorporation of G-E Idlematic control.

YOU WILL FIND IT EASIER TO OPERATE

Simply touch the electrode to the work, and you're off to a good weld. Idlematic control makes it as easy as that!

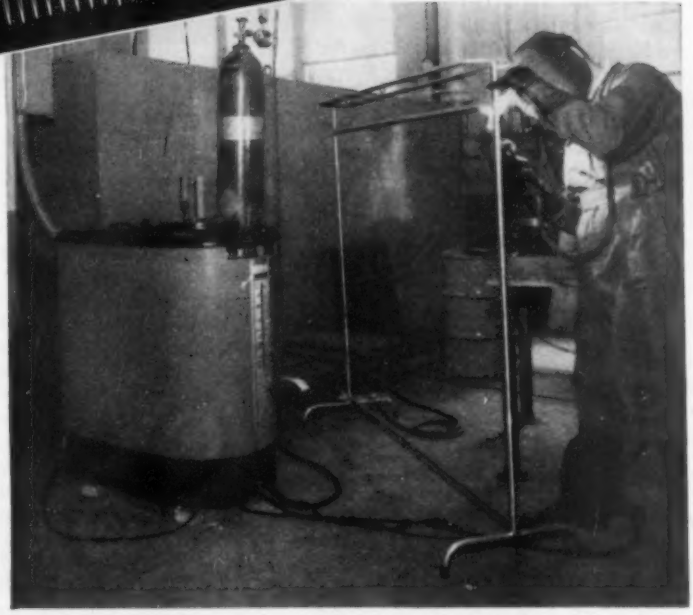
YOU CAN MAKE CLEAN STARTS

Easy striking and reduced tungsten consumption of the Idlematic Inert-Arc welder will save you time and money. Clean welds mean fewer rejects.

YOU GET AN ADDED SAFETY FEATURE

Accidental discomfort to the operator, from the open-circuit voltage of the welding transformer, has been eliminated.

Want to know more about savings in gas consumption—increased welding speed—better bead contour? See your G-E Arc-welding Distributor—or mail the coupon below.



In welding this sturdy, tubular, aluminum coat rack, the starts have been made neatly and easily, producing fine-looking, flux-free beads—thanks to the Idlematic control and balanced design of the G-E Inert-Arc welder.

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Apparatus Dept., General Electric Co.
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SOCIETY NEWS

A.W.S. OFFICERS ELECTED

Since no other nominations were presented in accordance with the By-Laws' provision, the following officers and directors will be elected to serve for the year 1948–49.

President, G. N. Sieger, President and General Manager, S.M.S. Corp., 1165 Harber Ave., Detroit, Mich.

First Vice-President, O. B. J. Fraser, Assistant Manager, Development & Research Div., The International Nickel Co., 67 Wall St., New York City.

Second Vice-President, H. W. Pierce, Assistant to General Manager, New York Shipbuilding Corp., Camden, N. J.

Directors at Large: J. J. Chyle, Director, Welding Research, A. O. Smith Corp., Milwaukee, Wis.; J. H. Humberstone, Director, Research & Welding Engrg., Arcrods Corp., Sparrows Pt., Md.; T. B. Jefferson, Editor, The Welding Engineer Publishing Co., Chicago, Ill.; H. N. Simms, Metallurgist, Black, Sivalls & Bryson, Inc., Oklahoma City, Okla.

District Vice-Presidents: District No. 2 (Mid-Eastern)—G. E. Claussen, Metallurgist, Reid-Avery Co., Inc., Baltimore, Md.; District No. 4 (Central)—F. L. Plummer, Director of Engrg., Hammond Iron Works, Warren, Pa.; District No. 6 (Mid-Southern)—R. L. Townsend, Partner, Tweco Products Co., Wichita, Kan.

MEETING OF BOARD OF DIRECTORS, AMERICAN WELDING SOCIETY

A meeting of the Board of Directors of the SOCIETY was held in the Pennsylvania Hotel, New York, N. Y., on Friday, July 16, 1948, with the following present:

Members: H. O. Hill, D. Arnott, R. S. Donald, O. B. J. Fraser, W. F. Hess, G. O. Hoglund, T. M. Jackson, A. B. Kinzel, C. I. MacGuffie, J. F. Maine, H. W. Pierce, G. N. Sieger and A. C. Weigel.

Members of the Publication Committee: A. G. Oehler, G. Van Alstyne and F. R. Hensel.

Staff Members: J. G. Magrath, W. Spraragen and M. M. Kelly.

Technical Assistant

Upon motion, duly seconded, it was voted to empower the Executive Secretary, with the assistance of the committees concerned and the Technical Secretary, to proceed with the employment of a technically trained man, with some practical and editorial experience, for the position of technical assistant to the Technical Secretary of the Society, and to effect the best arrangement within the salary range established for this position.

Special Committee Report on Review of Ballots on By-Law Amendments Pertaining to Dues Increases

Since the active membership on the date ballot was mailed to the membership totaled 7192, it was found that the negative vote on the amendments dealing with dues increases was negligible (less than 4%). Thus, the By-Law amendments were declared approved, having fulfilled all prescribed requirements of Article XX of the By-Laws

In the membership billing for the ensuing year, it was deemed proper to include a message from the President, expressing appreciation for the gratifying response to appeal for needed support, and the hope for acceptance by the entire membership of the dues increases, which, together with a substantial growth in number of members, will enable the SOCIETY to maintain its prestige and improve its services, and further, expressing appreciation to those members who added their comments to the letter ballot, assuring them that their comments will be studied and improvements made as quickly as economically possible. It was believed fitting that a similar message appear in THE WELDING JOURNAL over tabulation of the ballots on By-Law amendments; and that a special letter be sent to Sustaining Members.

Finances

Attention was drawn to the excess expense over income shown at the close of the nine months' operation ($14,234.62) which, while it compares unfavorably with the financial status at the end of the same period the previous year, is an improvement over that anticipated in the 1947–48 budget.

Attention was drawn also to "Request for Agreement to a Rental Increase in Office and Storage Space Occupied by A.W.S. in Engineering Societies Building." It was agreed generally that, inasmuch as rental had not been increased since 1919 and the SOCIETY has, over these years, enjoyed the privileges of office space in this building without being called upon to share the burdens of increased operational costs, it is in order to accept the proposed increased assessment on the SOCIETY'S office and storage space occupied in the Engineering Societies Building.

Membership

Report on membership changes during the nine-month period ended June 30, 1948 was distributed at the meeting. It showed a net change during the nine months of −58, and a total membership of 7342 (7145 members in good standing and 197 with dues in arrears).

The Executive Secretary reviewed briefly total over-all membership plans for the coming year, which include:

1. A very extensive 10-day campaign to be conducted by the Sections of the SOCIETY under the direction of Mr. Reehl, newly appointed Membership Committee Chairman, and the man responsible for a most successful drive in Milwaukee; the national campaign to follow the pattern of that of the Milwaukee drive. The proposed campaign was planned for early spring but was postponed, awaiting outcome of ballot on proposed membership dues increases. Plans now are to conduct the drive in the early fall. Preparative work on the drive will begin in about two weeks' time.

2. Preparation of a suitably attractive brochure which, in a dignified manner, will serve to acquaint potential industrial management with the SOCIETY'S purposes and functions and a list of its supporters.

The Board voted to approve, in principle, membership plans of the Executive Secretary. It favors an early fall nationally concentrated 10-day membership drive, conducted by the Sections under the direction of the National Membership Committee Chairman. It authorized the Executive Secretary to proceed with preparation of dummy of the proposed brochure for submittal, with costs, at the next Board meeting.

Report of Executive Secretary—Findings and Recommendations in Respect to Section Visitation

The Chairman recalled that this report had been distributed at the last Board meeting and, as directed at that meeting, copies have been circulated to absentee members of the Board and to the committees concerned, for study and with request

(*Continued on page 736*)

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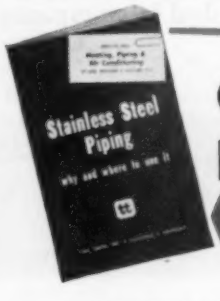

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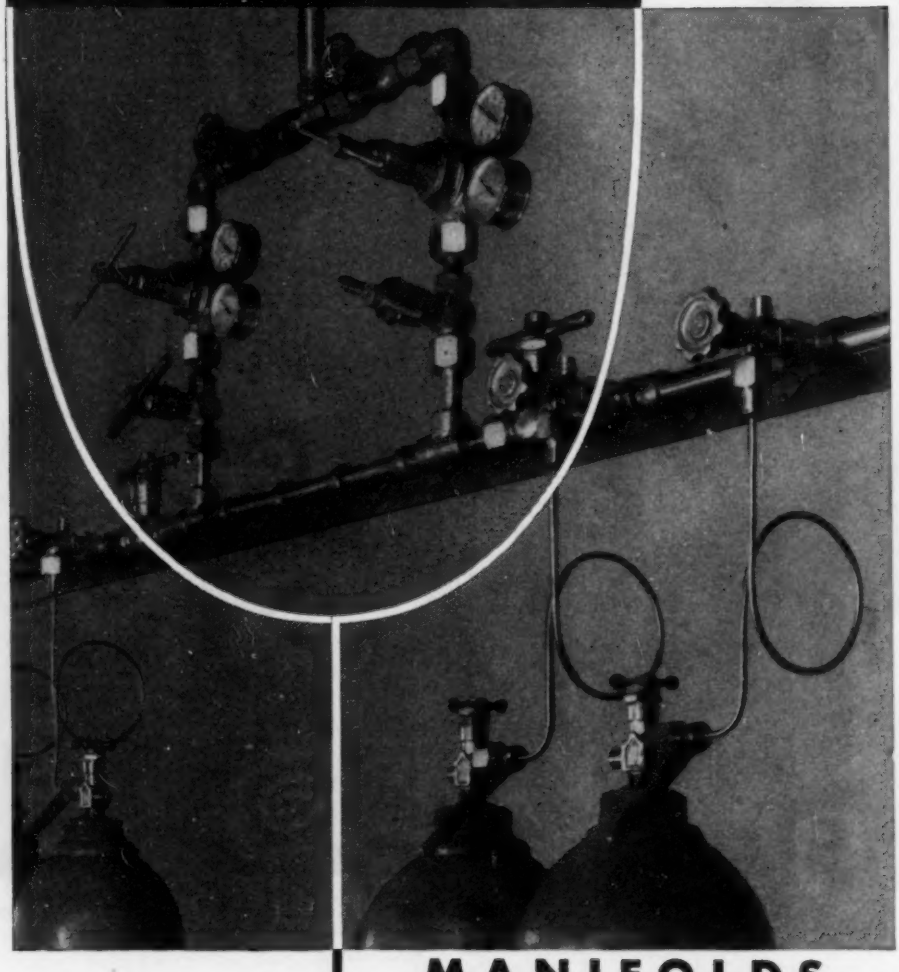

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Pioneer and Leader in the Design and Manufacture of Precision Equipment for Using and Controlling High Pressure Gases

(*Continued from page 732*)

that they submit their comments thereon to the Board of Directors in advance of the next Board meeting, when the report would be discussed and action taken thereon. The items were discussed in the order of importance.

Welding Journal—Before discussion commenced, the Chairman announced that the Publication Committee had been invited to the meeting for the purposes of listening to discussion and expressing their opinions. He introduced the members of the Committee in attendance, including, in addition to Mr. MacGuffie, a member of the Board, Messrs. Oehler (Chairman), Spraragen (Secretary), Hensel and Van Alstyne. Communication, containing comments of Mr. Fetherston, another member of the Publication Committee, was distributed at the meeting. Comments of Messrs. Wirt and Tinnon, Board members, had been circulated in advance of the meeting. Mr. Hill read portions of letter from Dr. Adams, commenting on the JOURNAL.

Generally, it was felt that the JOURNAL, as published presently, ranks high among technical publications and is outstanding in the welding field. It is and has been successful financially. Some change in format and content is needed to enhance the JOURNAL's value as an advertising medium and to make it more attractive as a membership inducement. From an economical standpoint, it is not necessary to make radical changes at this time, but rather to focus on restyling, briefing of articles where possible, and the inclusion of material on design and applications of welding, written by men actually performing these operations. It was believed that one good article a month, written in language understandable by production men, will prove satisfactory to those who now feel they are not getting the kind of material needed.

The Publication Committee Chairman stated that his Committee has considered, periodically, improvements in THE WELDING JOURNAL. Some of the ideas advanced at this meeting have received attention in the past, and where practical and economically feasible, improvement has been made. The Publication Committee Chairman endorsed heartily proposal that study be made of comments and recommendations for improvement in the JOURNAL, from which he believes his Committee will derive valuable information. Where found feasible, without jeopardizing the standing of the JOURNAL, or embarrassing the SOCIETY financially, the Board of Directors' sanction will be sought in effecting recommended changes.

The Publication Committee was given a vote of confidence and its Chairman was commended for the conciseness and brevity of his presentation.

On motion, duly seconded, it was voted that the Publication Committee take under advisement, at the earliest possible moment, matter of improving the SOCIETY's publication, giving due consideration to Sections' comments contained in the Executive Secretary's report, opinions expressed at this meeting, as well as those expressed in communications and questionnaire received from members of the Board and the Publication Committee;

40 Welds

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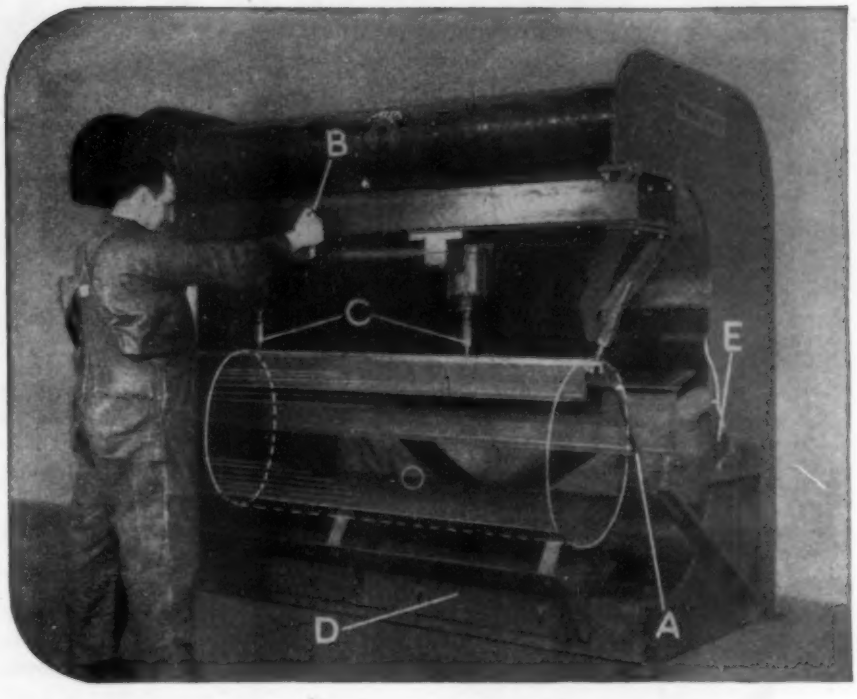
NO HANDLING OF THE WORK

Semi-Automatic { INDEXING
Automatic { WELDING
Automatic { SIZING



In this instance, interconnected traveling guns (C)—having adjustable spacing—are used to series weld shells for several different sizes of hot water heaters in high production. Mandrel support at (A) is swung out to the right for loading. When swung out it prevents machine operation through safety switch (E). Guns weld in series. Push button (B) initiates the welding cycle, but guns fire automatically when they are moved, as soon as they reach the next "weld" position. The support for the heater shell (D) is adjustable for different shell diameters. Machine may be easily re-worked to accommodate other welding jobs of similar weld characteristics.

. . . and the machine will handle two diameters and any length of water heater shells.

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For this story plus "Assembling Nash Suspensions"; "Traveling Gun Welders Solve Many Problems"; "Seam-Welding Panels from Strip"; etc., see . . .

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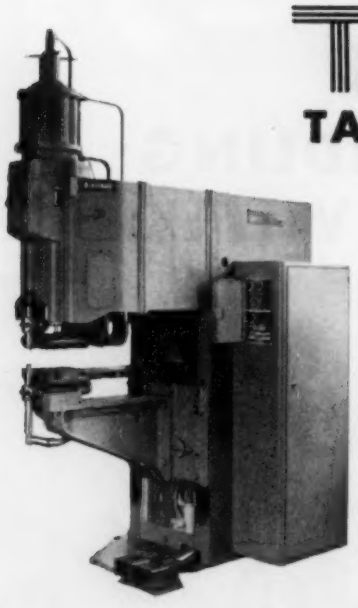
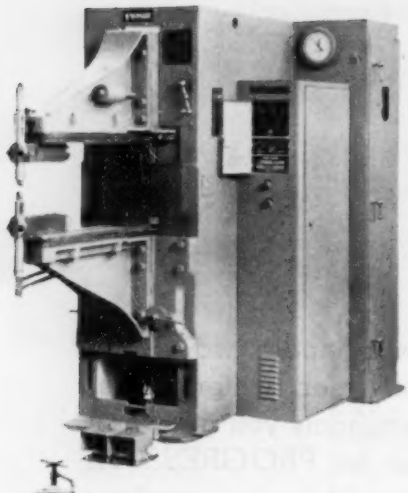
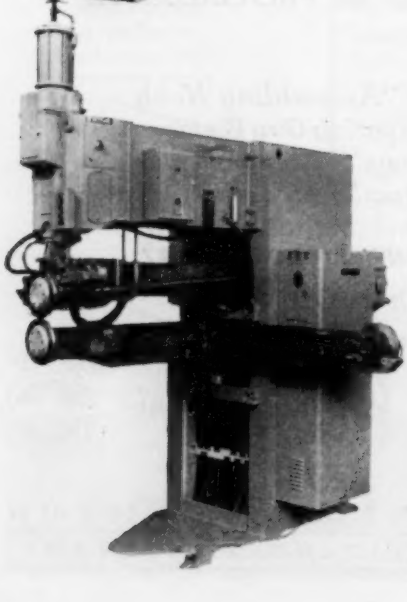
WELDERS
(RESISTANCE)







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RESISTANCE WELDERS

further, that the Publication Committee, after reaching conclusion on needed changes in the SOCIETY's publication, prepare statement of recommendations with estimate of costs thereof for submittal to the Finance Committee, in order that that Committee can be prepared to report to the Board of Directors on the financial possibility of meeting increased costs involved in carrying out recommendations of the Publication Committee; and further, that the Publication Committee report back to the Board its findings at the next Board meeting.

Publication of Ship Structures Committee Report

Memorandum pertaining to W.R.C. Director's request for running off reprints of report of the Ship Structures Committee, which appeared in the July WELDING JOURNAL, for sale to A.W.S. members and W.R.C., was distributed in advance of the meeting. Since it appears the SOCIETY will not suffer financially on this transaction, the Board approved of having reprints run off for sale at 50¢ per copy, and to insure against financial loss on sale of these bulletins, accepted offer of W.R.C. to purchase a sufficient number of the reprints.

Publication Year Book

It was reported by the Executive Secretary that a change in publication date and manner of issuance of the Year Book have been under advisement for some time. Regular date of publication is February, but because of heavy burden on staff due to membership billing, recording of payments, preparation and aftermath of Annual Meeting, and other items of this order coming due at the same time, as the preparation of the Year Book, the book is delayed a month or more in getting out. By the time it comes out, committee personnel, Section and other data is out-dated. A further development this year is need for republishing entirely, or in part, the annual report on SOCIETY's activities for the administrative year just ended. Heretofore this has been published in the JOURNAL, but because of necessity for effecting economies in publication costs, the annual report will not be republished in its entirety in the JOURNAL. The Executive Secretary offered suggestions for ways and means of handling the matter. It was believed necessary that the report on financial operations for the year should be published in permanent form and furnished to all members. It was believed unnecessary to repeat in the JOURNAL or Year Book, complete report of the technical committees. It is planned to publish report of the Executive Secretary on SOCIETY's activities for the administrative year just ended, in pamphlet form, but probably in 8 x 11-in. size.

It was moved that the Executive Secretary be requested to have ready for presentation at the coming Board meeting, recommendations for form and date of publication of the SOCIETY's Year Book, as well as costs in carrying out proposed plans.

BY-LAWS APPROVED

In the March 1948, issue of THE WELDING JOURNAL, page 225, under the "Activities-Related Events" Department, were published a number of Proposed Amendments to the By-Laws of the AMERICAN WELDING SOCIETY, as approved by the Board of Directors, at Buffalo, N. Y., on Feb. 26, 1948. Included were amendments to Article IV—Dues and Fees, proposing an increase in annual dues for all Member Classifications (*A*) through (*D*), and amendments to Rulings regarding membership qualifications and benefits.

As ordered by the Society's By-Laws under Article XX, "Amendments," not less than 30 days after publication in THE WELDING JOURNAL, the proposed Amendments were submitted to the membership for letter ballot. In submitting these amendments the President frankly told the members the SOCIETY needed the support, and explained the reasons for requesting a dues increase. In a communication to the membership the President states:

"Your response has been most gratifying. Less than 4% maximum, (3.58% exact) of our total membership voted in the 'negative.' Further, a careful study of the 'negative' letter ballots indicated that a number of those members so voting, would have voted affirmatively had they the opportunity to minutely study the present day demands upon your SOCIETY for additional beneficial activities.

"Your better than 96% approval is accepted by your Board of Directors with their sincere appreciation. Accordingly, your President announces your approval and your SOCIETY's adoption of the By-Law Amendments, as published and balloted, including those amendments pertaining to dues increases, all to be effective immediately.

"The increase in dues have been kept to a minimum. In that the financial returns to your Sections are based upon a fixed minimum fee and a percentage of the dues, they will receive a fixed percentage of the increase. Of itself, the increase will not balance the national budget without a substantial growth in the number of members over our present enrollment. Toward such end our National Membership Committee is planning a membership campaign for this Fall and we know that you will desire to assist in every way possible toward bringing the WELDING SOCIETY benefits you have enjoyed to others, among whom may be many of your friends and industry associates. We are counting upon the wholehearted assistance of our total membership toward assuring a successful campaign.

"It is our hope that the expected improvement in your SOCIETY's financial position as anticipated resulting from the combination of increased dues and increased membership, will provide sufficient revenue for maintaining your SOCIETY's prestige and improving its present services as well as increasing the benefits to all classes of membership.

"Let us now look forward to and work for a continued and most successful growth of our Society—in prestige, in enrollment, and in benefits."

Use Ampco-Weld resistance welding electrodes with modern machines—to boost your weld-per-hour production and cut your costs

Every hour this Precision Welder completes 125 washer housings — spot welding 24 angle clips (4 welds each) on every housing. The manufacturer had hoped for 75 an hour. Resistance welding gave him nearly twice that volume.

That's why modern production methods call for resistance welding — the fastest, most economical way of joining two pieces of metal.

Men who know production welding can also tell you that it pays to use Ampco-Weld electrodes in your resistance welding set-up — for clean, strong welds, longer electrode life, and real welding economy. The Ampco-Weld line is complete with tips, wheels, dies, standard and special holders made of metals with the highest properties attainable. All products meet R.W.M.A. specifications. Call the nearest Ampco office for complete data. Write for the latest Ampco-Weld bulletin.

MEMBER RESISTANCE WELDER MANUFACTURERS ASSOCIATION RWMA

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A.W.S. BY-LAWS REWORDED

The wording of Article II, Section 1, has been revised as follows:

"Approval of Membership Applications—All applications for membership shall be *subject to* the approval of the Committee on Admissions."

The changed wording is a recommendation of the Special Committee on Review of Returned Ballots on Recent By-Law Amendments. The Committee believes the change clarifies wording without changing sense of by-law.

LETTER TO THE EDITOR

Dear Sir:

In the May 1948 issue of THE WELDING JOURNAL there appeared a letter signed by J. F. Lincoln, President of The Lincoln Electric Co., which is entitled to recognition as an effort to improve Code Rules for the construction of welded pressure vessels.

I offer the premise that Code writers are just as intent upon formulating the least restrictive rules, consistent with safety, as the manufacturers of equipment are intent upon doing an honest job in proving and selling their products. If there is any "cussedness" in the make-up of any group, I believe it is sporadic and that it can be ignored in debating issues which are to be decided solely on their merits.

I infer that, in adding his general remarks, Mr. Lincoln was thinking about all types of welded structures, even though at several places pressure vessels are definitely mentioned.

Not to extend this letter unduly, I merely cite, as part of the background for present rules, extensive published results of tests, and the most excellent work done by Mr. Lincoln's own experienced engineers and technicians. Their specialized leadership and experience in the four phases of arc welding advancement—research, manufacture, application aid and educational work—are expressed in The Lincoln Electric Co.'s "Procedure Handbook of Arc Welding Design and Practice."

It would appear from the manner in which Mr. Lincoln's viewpoint is presented that he was only outlining a comparison on quality and a seeming prejudice in choice as between a welded and a riveted joint. Broadly speaking, under these two classifications only, it has been the idea of almost all engineers I know that the welded joint is preferred for pressure vessels, subject to adequate specifications for material, rules for construction, and qualified inspection all along the line, for which we, as engineers, are willing to approve the cost.

In a general comparison between riveted and welded work—and the writer has had experience with both, from early practices when hand operations in riveted work were quite common, and from the beginning of electric fusion welding—may we not recognize that riveting is now more or less a machine job, except for inspection? Its fabrication makes use of repetitive methods that cannot but result in the best type of workmanship, and a uniformity that meets the accepted method of computation.

On the contrary, welding is still largely a manual operation, dependent upon quality of workmanship, and therefore upon the individual skill and integrity of the welding operator, foreman and inspector.

As to the nine items of comparison between the welded joint and the riveted joint which Mr. Lincoln cites, they should be valued in proportion to their relative importance. It is usually conceded that the breaking strength in a pull test on mill specimens is not the principal quality desired, because of the many variables that may be introduced, from the time that the steel is in the making until the vessel has been in service for a time. Quality of finished welds as regards ductility, fatigue value and tendency to resist corrosion of any type, may be important and is dependent on the quality of the base material as well as the procedure used in welding.

Some defects in welds, which Mr. Lincoln merely lists in his letter, may alone be of little consequence, but in combination with others and service factors may cause trouble.

Under defects limited by Code Rules may be classed lack of fusion, incomplete penetration where it is barred, gas pockets and slag inclusions, and surface appearance. Undercutting is barely mentioned in construction codes, as "practically none" is a recommendation only. In general, slight undercuts are not a cause for rejection. Serious examples of porosity may not be as indicated by the present A.S.M.E. standard films, but user demand has largely set the present requirements.

As methods of examination improve, and instrumental indications of a nondestructive kind give greater assurance of having the minimum soundness and ductility in a welded joint in accordance with its efficiency rating, we can expect more liberalized standards to be set up. Mr. Lincoln's staff is well aware of all such developments in technique and is obviously interested in improving them.

In summary, I advocate the writing of rules to produce safe structures at minimum cost. Doubtless, this is Mr. Lincoln's objective, too. Its attainment will surely require mutual effort, compromise and the test of time.

In my capacity as Chairman of several Unfired Pressure Vessel Committees, including the Pressure Vessel Research Committee, and having helped to write codes for pressure vessels, I am hereby extending an invitation to Mr. Lincoln for an oral discussion on this subject, to the end that we may reach a common understanding of mutual problems. At the same time, if it is necessary to do some more research work to resolve some of these questions, I feel that he will recognize this need, and gladly join in any cooperative effort to discover what the industry at large now lacks.

Yours very truly,

(Signed) WALTER SAMANS*

* Chairman, Pressure Vessel Research Committee; Chairman, Subcommittee on Unfired Pressure Vessels of the Boiler Code Committee, A.S.M.E.; Chairman, Joint API-ASME Committee on Unfired Pressure Vessels.

PRACTICAL ARTICLES

The Publication Committee is anxious to secure short practical articles that will be of interest and help to the practical welder, foreman and supervisor and to the designer.

If any member has finished the design or welding of an interesting application of welding, he is strongly urged to write it up and send it to the Editor with suitable sketches or photographs.

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RACO Composite Type A is a heavily coated electrode in coils, providing the same physical results as heavily coated manual electrodes. With RACO Composite Type A, extremely high speeds can be obtained.

It can be used with all standard automatic arc welding heads with the addition of adapter and contact device illustrated.

RACO Composite Type A can be had with any of the following coatings—A.W.S. 6012; 6020; 6030; 7020; 7030, and corresponding high tensile grades A.W.S. 8020; 8030; 9020; 9030; 10020; 10030. This electrode can also be furnished in three grades of hard surfacing material for building-up—RACO 25 (20-25 Rockwell C), RACO 45 (40-50 Rockwell C) and RACO 55 (50-60 Rockwell C). RACO Composite Type A Electrode is furnished in the following sizes: No. 8 (approx. 3/8"), No. 7 (approx. 5/16"), No. 6 (approx. 1/4"), No. 5 (approx. 7/32"), No. 4 (approx. 3/16"), and No. 3 (approx. 5/32"). Coils are 36 inches I.D., and weigh 100 to 150 pounds net.

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We draw a full line of copper coated oxy-acetylene welding wires. Furnished in coils and straightened and cut lengths.

We further manufacture a complete line of heavy coated manual electrodes for welding:—Mild Steel—High Tensile Steels—Stainless Steel—Manganese Steel—Cast Iron—Nickel—Monel—Inconel and Aluminized Steel.

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NEWS OF THE INDUSTRY

SAFETY CONGRESS

The 36th National Safety Congress and Exposition, sponsored by the National Safety Council, will be held in Chicago from October 18th through October 22nd. Five leading hotels will house the safety sessions and expositions. They are: Stevens hotel, for the industrial safety exposition and industrial sessions; Sherman hotel, for the public safety exposition and traffic, farm, home and women's safety sessions; Morrison hotel, for industrial and school and college sessions, and Congress and La Salle hotels, for industrial sessions. For further information, write to George E. Burns, National Safety Council, 20 N. Wacker Drive, Chicago 6, Ill.

RAILROAD FAIR

The big national Railroad Fair, opened along a mile of Chicago's lakefront Tuesday, July 20th—first great public attraction of its kind ever sponsored by industry in this country—will give its hundreds of thousands of visitors a chance to inspect railroad locomotives and cars from the inside out, and from the bottom up.

In announcing the complete list of railroad rolling stock to be displayed on $2^1/_2$ miles of special exhibit track at the forthcoming railroading centennial, Maj. Lenox R. Lohr, president of the Railroad Fair, also pointed out that the public will view the most complete assemblage of locomotives and cars ever collected in one place for a nonoperating purpose.

This gigantic track display will be entirely in addition to the national Railroad Fair's 50 acres of spectacular outdoor pageantry, exhibits and entertainment on a scale unmatched in this country since the war.

To show how a modern Diesel locomotive operates, the Electro-Motive Division of General Motors Corp. will exhibit in the track display a locomotive unit with side panels, machinery covers and housing cut away. Other features of the Electro-Motive exhibit will be the widely publicized Train of Tomorrow with its dome cars and many other suggested improvements; a mobile instruction unit or school-on-rails in which 51,000 Diesel engineers have been trained; and a 6000-hp. 4-unit Diesel locomotive.

Pullman-Standard Car Manufacturing Co. will show an upside-down underframe of a sleeping car with a high ramp above for spectators. Also in the Pullman-Standard exhibit will be one of the first boxcars ever built to stock specifications instead of individual specifications.

Scheduled to be open through the summer, the Railroad Fair is being presented by 38 of the leading railroads of the country to tell in dramatic fashion the full story of railroading in America. Occasion for the mammoth celebration is the centennial of the first run of a railroad steam locomotive out of Chicago, the event which led directly to final conquest of the west and rise of Chicago as the nation's rail hub.

Locomotives and cars on the special exhibit tracks will represent all periods of railroad progress and, in addition, point the way to future developments.

VICTOR OPENS CHICAGO OFFICE

Victor Equipment Co., manufacturer of flame-cutting apparatus and distributor of welding supplies for 38 years, formally opened its new Chicago branch office and assembly plant at 1312 West Lake St., on Friday, July 16th. This step is in line with Victor's postwar expansion designed to give a country-wide service.

L. W. Stettner, president of the company, and W. S. Fulwider, secretary-treasurer, were in Chicago to aid in opening the new location. Utilizing every hour, company personnel stocked and equipped the empty building in just two weeks before the opening. The assembly line started operations the following Monday.

Carl Peterson, branch manager, and Dorsey Twedie, office manager, estimated that more than 200 distributors, manufacturers and shop operators attended the opening. Refreshments were served from 3:30 to closing time at 11:30 P.M.

The new Victor Branch will handle the Miller Electric, Stoody, Jackson, Handy & Harman, Sight Feed, Thor, Plomb, Lyon Metal, American Optical, Hewitt Rubber, General Electric cable and other leading lines of equipment besides their own Victorweld Electrodes and Arc Welders.

PROPERTIES AND USE OF EYE-PROTECTIVE GLASSES

In keeping with general industrial progress in this country, protective glasses and goggles have been developed and improved until today there is a glass or goggle available for adequate protection in every occupation and avocation. Recently, an investigation was made by Ralph Stair at the National Bureau of Standards covering the spectral-transmissive properties of about 200 glasses intended for use as sunglasses or for special industrial operations where injurious amounts of ultraviolet, luminous or infrared radiant energy are present. Extensive consideration was given to the elimination of glare, the distortion of colors of objects, the use of glasses for driving at night, the standardization of glasses for out-of-doors and industrial purposes, and the spectral-transmissive properties of glasses for use under various types and intensities of radiant energy.

LINCOLN FOUNDATION ANNOUNCES RECIPIENTS OF SCHOLARSHIPS AND AWARDS IN FIRST ANNUAL ENGINEERING UNDERGRADUATE PROGRAM

Awards of $1000 to the University of Cincinnati, $500 to the University of Minnesota and $250 to Iowa State College were announced recently by The James F. Lincoln Arc Welding Foundation. These awards are to be used for providing scholarships in each school.

The awards represent top honors in the Foundation's Annual Engineering Undergraduate Award and Scholarship Program in which awards are given to engineering undergraduates for the preparation of papers on arc welding and its uses. The scholarship funds are awarded to the schools in which the authors of the three best papers were registered and duplicate similar cash awards to each author. Papers were submitted by students from 46 different engineering colleges in all parts of the country.

The paper, "Standardized Welded Building Structures for Railroads," received the first award of $1000 for Alan R. Cripe of the Department of Architecture, University of Cincinnati, Cincinnati, Ohio, and, in addition, the honor of having the four scholarships awarded to the University named in his honor. Mr. Cripe resides at 831 Harvard Blvd., Dayton 6, Ohio.

The paper, "Arc Welded Design as Applied to a Combination Hay Buck-Stacker," written by William David McCoy, undergraduate in the Electrical Engineering Department of the University of Minnesota, Minneapolis, Minn., received the second award of $500, with like amount going to the University for scholarships in his name. Mr. McCoy resides at Pioneer Hall, University of Minnesota; his home being in Duluth.

The third main award went to William W. Robinson of the Mechanical Engineering Department of Iowa State College, Ames, Iowa, as author of the paper, "Vises Fabricated by Arc Welding vs. Cast Vises." A similar amount went to the College for a scholarship named in his honor. Mr. Robinson resides at 115 N. 33rd St., Omaha, Nebr.

In addition to these, smaller awards totaling $3500 were made to 68 undergraduates representing 43 engineering colleges and universities.

The Annual Engineering Undergraduate Award and Scholarship Program of the Foundation was announced October 15th of last year and closed May 15th of this year. Judging of the papers was conducted by Dr. E. E. Dreese, chairman of the Board of Trustees of the Foundation and head of the Department of Electrical Engineering at Ohio State University. Dr. Dreese was assisted by Professor Justus Rising, Department of General Engineering, Purdue University, and Professor Kenneth E. Quier, Department of Mechanical Engineering, Pratt Institute, Brooklyn, N. Y.

The closing of this program marks the end of the first of a ten-year series of annual competition for engineering students.

The purpose of this program, as stated in the rules, is to encourage the study of design for arc welding through the prepara-

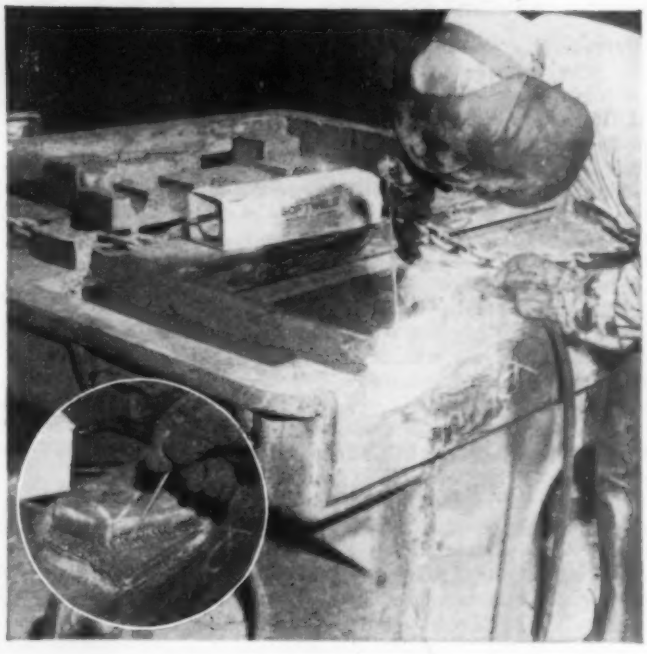
Machinable Welds In Cast Iron Improved With New "Softweld"

USERS of the New Lincoln "Softweld" Electrode report greater ease of welding, better welds and easier machining of the weld deposit.

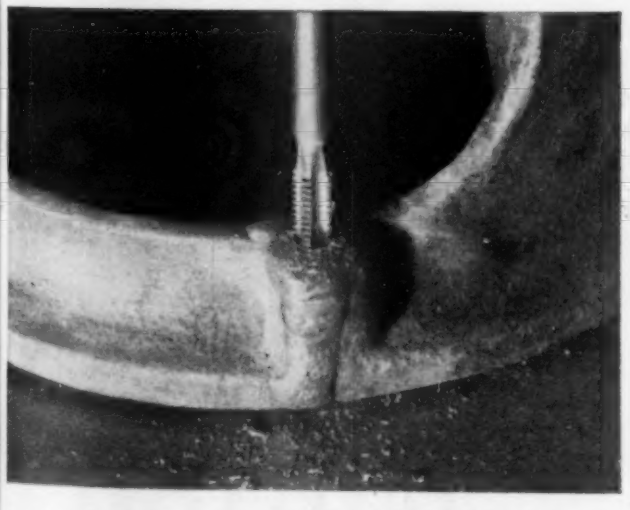
Easy Operation. The New "Softweld" operates with a steady, soft arc with either A.C. or D.C., and on either polarity of D.C. Where conventional electrodes of this type melt-off in large drops of spatter and the coating flakes off, the melt-off of this New Lincoln Electrode is uniform. Smoke is light and slag removal is easy.

Dense, Soft Deposits. This improved shielded arc electrode deposits a non-ferrous alloy on cast iron with minimum penetration and heating of the base metal. The entire weld area then may be machined, ground, sawed, drilled or tapped with ease.

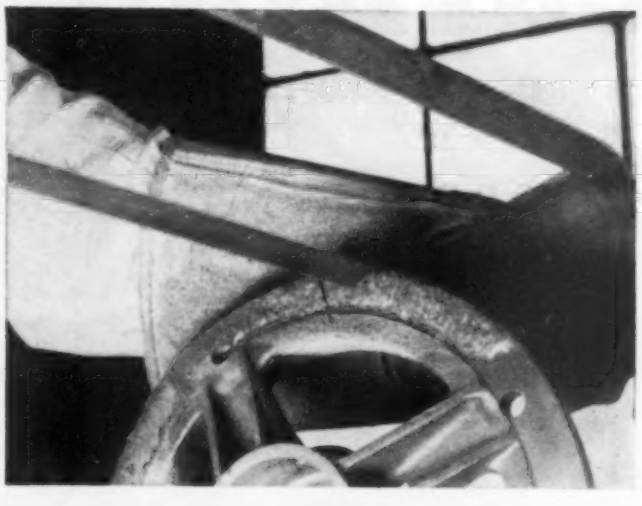
Surface of the deposit and the fusion zone have less porosity than those of former electrodes. Bead appearance is good. Ability to build up an edge also has been improved.



Broken off, the corner of this machine tool bed casting is being built up with the new "Softweld." Inset shows repair when partially complete. When welding is complete, the area will be machined to proper size and shape.



Break in motor bracket, welded with "Softweld." Deposit and fusion zone can be easily drilled and tapped.



Cutting through a deposit and fusion zone of "Softweld" deposit with a hacksaw illustrates how soft it is.

The above is published by LINCOLN ELECTRIC in the interests of progress. For further information on the new "Softweld," write The Lincoln Electric Company, Dept. 109, Cleveland 1, Ohio.

Advertisement

tion of papers by students of engineering in institutions of higher learning upon whose shoulders rests the responsibility for future industrial progress.

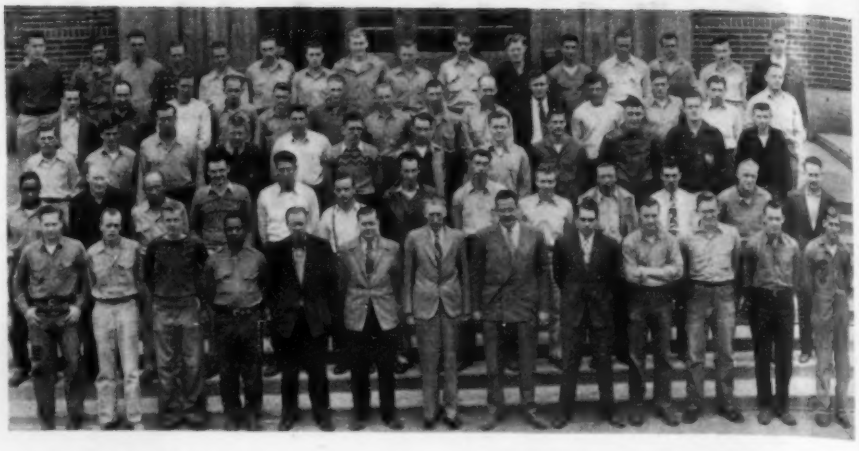
The present study indicated that while arc welding is being applied extensively, there remain innumerable applications for still further economic utilization of the arc process.

WELDING STUDENTS

Heading for jobs in the welding field are the men pictured in the accompanying photograph, students in the Welding Dept. at Dunwoody Industrial Institute in Minneapolis, Minn., and part of the 5790 who have been receiving trade training there during the past year. In the day school regular pre-employment training, 3022 attended, and in the evening school extension training, 2768.

Shown with them is the department head, Marcus Maynard, seventh from the left in the front row, and the instructors, also in the front row, who are teaching the intricacies of gas, arc and atomic hydrogen welding.

In their quest for job knowledge, students at Dunwoody put in 1,949,847 hours of training. They came from Minnesota and 38 other states, and these foreign countries: Canada, Hawaii, British West Indies, Venezuela, Brazil, Porto Rico, Panama, Iceland, France, Alaska, Mexico, Costa Rica, Columbia and the Philippine Islands.



Dunwoody will begin its 35th year of training men for trade work with the reopening of school in August.

DR. SAUVEUR MEMORIAL ROOM

Dedication of a Memorial Room to the late Dr. Albert Sauveur, pioneer in the science of Metals, will take place in the National offices of the American Society for Metals, Cleveland, On August 19th, according to an announcement by W. H. Eisenman, the Society's National Secretary.

Dr. Sauveur, affectionately known throughout the metallurgical world as "Dean of American Metallurgists," was Gordon McKay Professor of Mining and Metallurgy at Harvard when he died in 1939.

The Memorial Room, which occupies a space 40 x 15 ft., has been completely redecorated and equipped with built-in, glass-enclosed cases for displaying the many records and honors belonging to Dr. Sauveur. Dominating the room will be an oil painting of the scientist, executed by Alexander Smith, outstanding portrait artist. Professor Sauveur's desk and chair, his medals, awards and other memorabilia will be on display. Other items of historic interest, not connected with Professor Sauveur, will be an early Rockwell hardness testing machine, a complete set of the writings of the late Dr. John A. Mathews and many photographs and letters of other honorary members and winners of the A.S.M. Sauveur Achievement Award, of which Dr. Sauveur was the inspiration and first recipient.

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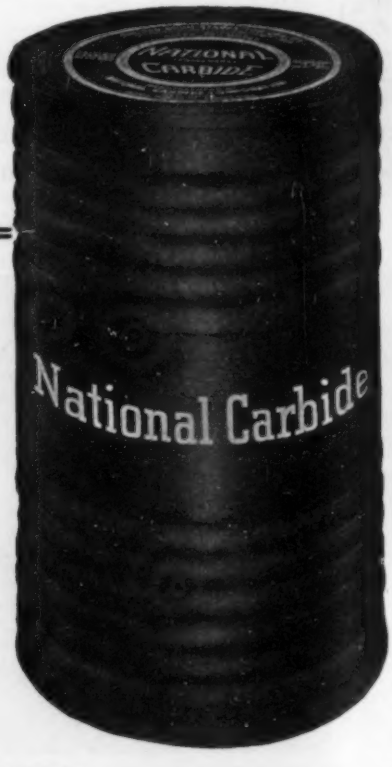

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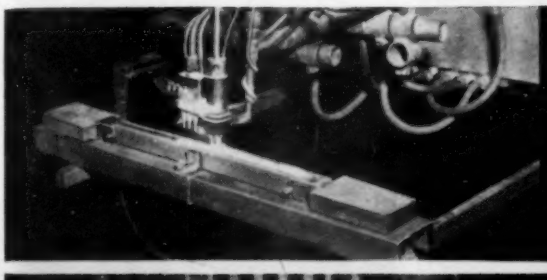
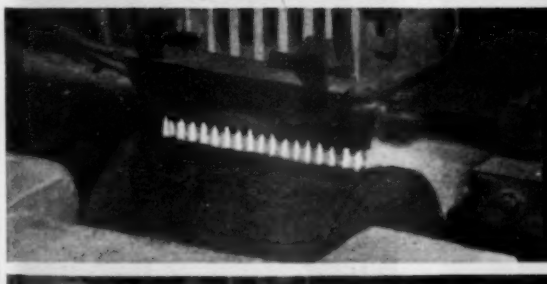
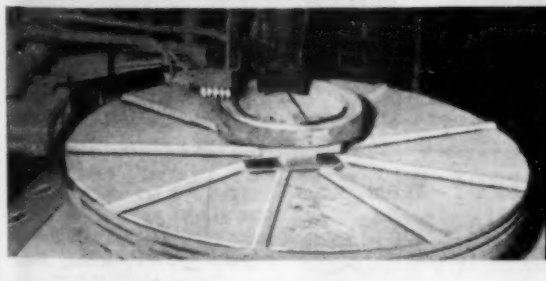


1. STRAIGHT LINE —for relatively long, narrow surfaces like knives.



2. CYLINDRICAL — for parts such as pump rods, sleeves, and bushings.



3. CIRCULAR — for gate valves and other circular pieces.

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For full information on mechanized hard-facing, write to Haynes Stellite Company, Kokomo, Indiana. If you want help in determining whether any job in your shop should be mechanized, ask to have a service engineer call.

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The dedication ceremonies, which will take place at 3:00 P.M., at the American Society for Metals' National headquarters building, 7301 Euclid Ave., Cleveland, will be attended by the National Officers and Trustees of the Society, by Mrs. Sauveur, widow of the noted metallurgist to whom the museum is dedicated, and by any members of the American Society for Metals who would like to attend. Dr. Sauveur was an honorary member of the Society.

Chairman of the committee responsible for the Memorial Room is H. H. Lester of Watertown Arsenal. Other members who, with Dr. Lester, were former pupils of Dr. Sauveur, include G. B. Waterhouse of M.I.T.; V. N. Krivobok, International Nickel Co.; Joseph Winlock, Edward G. Budd Mfg. Co.; James P. Gill, Vanadium Alloys Steel Co.; Bradley Stoughton, Lehigh University; and Secretary Eisenman of the Society, complete the committee.

A Communication to the Society

Shanghai, 31st July, 1948

The Jardine Engineering Corp., Ltd., has been carrying out repairs on a number of 225-hp. Marine Diesel engines for the Chinese Maritime Customs. The defects were of a similar nature in all cases, and consisted of numerous cracks and pores in the upper part of the waterjacket, and in some cases considerable chunks of metal were broken away, as can be seen from Illustration No. 1.

To gain access for preparatory work and the subsequent welding operations, windows were cut, as shown in Illustration No. 2. As cracks were detected adjacent to the gap, the waterjacket was cut out the full length of the cylinder wall.

It was decided to use wrought iron for the patch, which itself was fabricated from two pieces welded together, before being fitted to the opening in the waterjacket and welded to it, see Illustration No. 3. The welding of the motor block was carried out without preheat, $^{5}/_{32}$-in. Nickel Alloy Electrodes being used, applied in interrupted beads of $^{1}/_{2}$ in. in length with subsquent light peening. After allowing the weld to cool off, welding was resumed, welding current of 120 amp. was used.

Fig. 1

Fig. 3

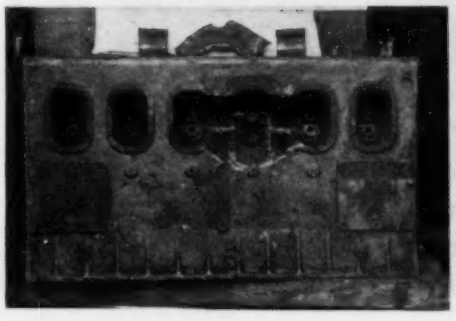


Fig. 2

Fig. 4

Perous welds were removed and rewelded until satisfactory.

After completion of the weld the waterjacket was subjected to a water test of 30 lb./sq. in., and no leakage or sweating occurred. The normal working pressure in the waterjacket of a Marine Diesel is, of course, almost negligible.

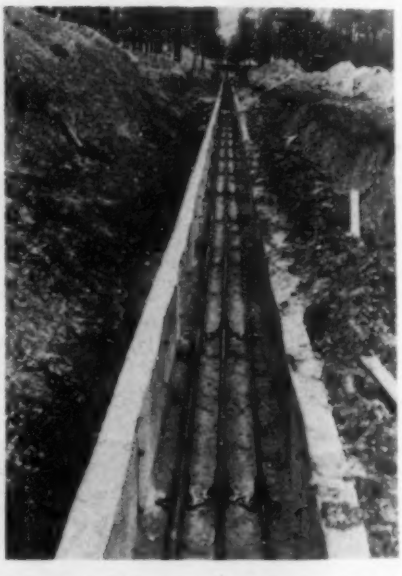
Illustration No. 4 shows the closing up of the block in progress.

The Jardine Engineering Corp., Ltd., has repaired a number of these engines for the Chinese Maritime Customs, and the earlier ones have now been back in service for several months to the complete satisfaction of the owners.

(Signed) GEORGE O. DRUCKER,
In charge of the Welding Sections,
of The Jardine Engineering Corp., Ltd.

STEAM LINES

Long runs of new steam supply and return mains at the U. S. Department of Agriculture's Research Center, covering 12,000 acres near Beltsville, Md., are placed in concrete tunnels that are covered by concrete slabs. These lines run from the institution's steam plant to Zoology buildings, and consist of $2^{1}/_{2}$- and $1^{1}/_{2}$-in supply pipes and 1-in. returns. Both the soil conditions and boiler feed water are extremely corrosive, it was reported, and wrought iron piping is used throughout the system. Welding was used for all joints. About 2000 ft. of 6-in. wrought iron pipe will be installed at a later date between the steam plant and buildings in the animal husbandry section.



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ORDERS FOR RESISTANCE WELDERS JUMP 13% IN SECOND QUARTER

A further increase in new orders by industry for resistance welding equipment is reported for the second quarter of 1948 by the Resistance Welder Manufacturers' Association. According to T. S. Long, President of the Association, new orders received by member companies during April, May and June, exceeded first quarter orders by 13% and were over 22% ahead of shipments for the entire year of 1938.

The vast increase in demand since the end of the war for this type of equipment—comprising spot, projection, seam and flash welders—is an indication of the current efforts being made by industry to reduce manufacturing costs, increase production and improve quality of metal articles according to Mr. Long who points out that industries which never before used any appreciable amount of this type of mass production equipment are now re-designing their products to enable faster production at lower cost.

LICENSING EXAMINATION

To further extend the usefulness of its Evening Division to graduate engineers of the upper Hudson region, Rensselaer Polytechnic Institute with the fall term will offer two courses especially designed to prepare engineers for the semiannual New York State licensing examinations.

For engineers whose practice has been confined to some special field, the courses in structural design and in the application of basic engineering science are expected to prove valuable refreshers in the broader phases of the technological professions.

The State's licensing tests are usually held around January 1st and July 1st. Only graduates of an accredited engineering school or its equivalent are eligible. In addition they must have had four years of responsible professional experience. Part I of the tests is in structural design. Part II is in application of basic engineering science and involves the solution of typical problems in hydraulics, thermodynamics, electricity and magnetism, and other basic fields. In Part III the candidate's particular professional capacity is tested. Applicants who have not had the required four years of experience may take Parts I and II for certification as Engineers-in-Training.

R.P.I. will receive applications for the Evening Division Courses until August 20th. Classes open September 20th. The two new courses are in addition to regular undergraduate and graduate courses in engineering and science which the Evening Division offers for credit toward degrees. Two hundred adult students, some of them attending from points 50 miles and more away, attended classes of the Evening Division in the spring term.

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FUEL OIL TANK

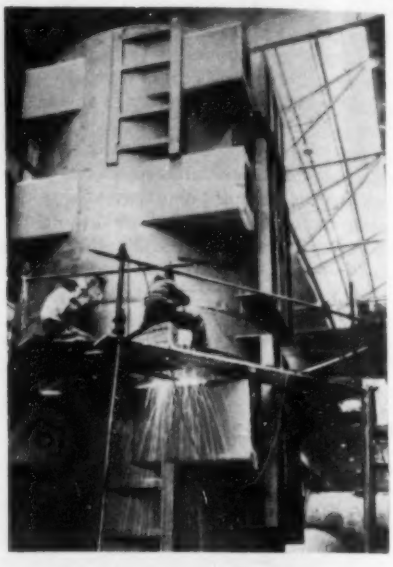
The largest rectangular fuel oil storage tank in the United States covers one complete city block in New York City and will hold the entire load of an ocean going tanker. The total capacity of the tank is 13,000,000 gal. of fuel oil. The tank is 300 ft. by 200 ft. by 30 ft. high and is divided into four oil-tight compartments. The 2000 tons of steel were largely prefabricated into panels and then erected on the site. The structure is all welded. Lincoln Electric "Fleetweld No. 7" 1/4-in. diam. electrode was used for all butt welds that could be done in a flat position. All out of position work was done with 5/32- and 3/16-in. diam. "Fleetweld No. 5."

The tank was built by J. K. Welding Co. of Yonkers, N. Y., for the Petroleum Terminal Oil Corp. and required five months to complete.

WELDING TURBINE GENERATOR

Welders in General Electric's Schenectady Turbine shop are shown joining the two 15-ft. sections of a stator frame of a 150,000-kw. turbine generator, one of the largest ever built by the company. Because of its tremendous size, and to facilitate manufacture, it was necessary to fabricate, anneal and machine the frame in two sections. This is a 1800-rpm., hydrogen-cooled unit.

According to G.-E. traffic specialists, the assembled armature, including core and windings, will weigh more than 400,000 lb. and will be the heaviest single-car ship-



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ment ever planned by the General Electric Co. A special 8-axle railroad car, following a route which already has been carefully planned by the company's traffic specialists, will carry the 30-ft. stator frame to its destination.

FLOATING DRY DOCK

Maintenance and repairing of most of the 234 vessels operated by the Erie Railroad in and around New York City now is being accomplished on a new welded steel floating dry dock, the only one of its kind owned by a private fleet operator in the New York harbor.

The 400-ton dock recently was put into service at Erie's Marine Terminal, Pier 1, North River, Jersey City, N. J. It was designed by engineers of the Erie Railroad and Dravo Corp. and constructed by Dravo at its Wilmington, Del., shipyard. Design of the vessel is similar to, but much smaller than, a huge floating dry dock built several years ago by Dravo for the U. S. Navy, Bureau of Yards and Docks.

The new equipment will permit more effective utilization of Erie's marine repair facilities that were enlarged in 1942, but did not permit work below the waterline. Thus, when repairs were necessary to both the hull and the superstructure of a boat, part of the job had to be undertaken at the Erie yard and the remainder at an outside yard equipped for such work.

Floating equipment operated by Erie in New York harbor includes 5 ferries, 11 tugs, 27 carfloats, four self-propelled lighters, 111 barges, 61 scows, one steam derrick and 14 gas hoist lighters. In the near future, 25 new barges and scows, two new carfloats and one tug will be added to the Erie fleet.

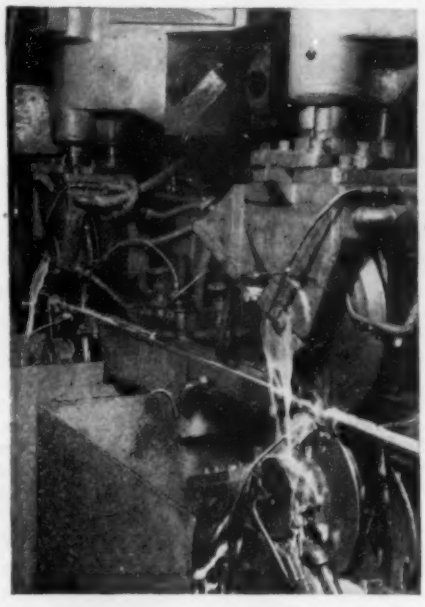
Some of the vessels, such as the ferries, are too large to be handled in the new dry dock and these still will be sent to outside repair yards when hull work is required. Most of Erie's equipment, however, can be serviced in the dry dock. These include all tugs, barges, scows and small lighters.

For many years, Erie has had a regular and well-organized marine inspection program. All equipment is examined at specified intervals and ordered into the yard for repairs as necessary. Welded steel vessels now will be dry docked annually for cleaning and painting, according to M. B. Roderick, Superintendent of Erie's Marine Dept.

The new dock is operated by a crew of six under supervision of a dockmaster. The crew is assigned to other work when their services are not required for docking. Berthing facilities for the vessel were dredged to a depth of 35 ft. in Erie's slip off the North River. The dock submerges in 20 min. and pumps out in 51 min. (pumping time).

Main hull of the vessel is 110 ft. long, but outriggers at each end increase the over-all length to 130 ft. The wing walls are 5 ft. 6 in. wide at the top deck and 6 ft. at the dock floor. In the aft outrigger, a 24-in. slot with three sectional hinged plate covers has been fitted for dropping rudders of tugs. A 3-ton power hoist, on the aft end of the port wing wall, facilitates removal of propellers.

THEY DON'T SPEAK—



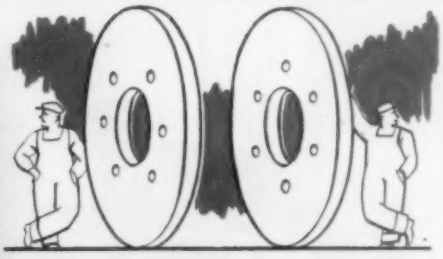


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Fig. 1—Dock Is Submerged as Harbor Tug, *Cleveland,* Is Maneuvered Into Position for Lifting. This Was the First Tug Docked in the New Equipment. Drydock Is the Only One of Its Type Owned by a Private Fleet Operator in New York Harbor

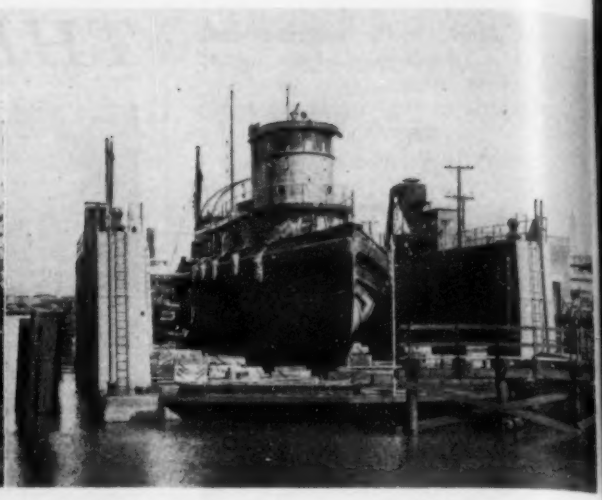


Fig. 2—Note Ample Freeboard with the 400-Ton Tug, *Cleveland,* Securely Blocked in Place. Addition of the Dry Dock to Erie's Enlarged and Modernized Marine Repair Facilities Will Now Permit Underwater Work to Proceed Simultaneously with Other Repair and Maintenance Service

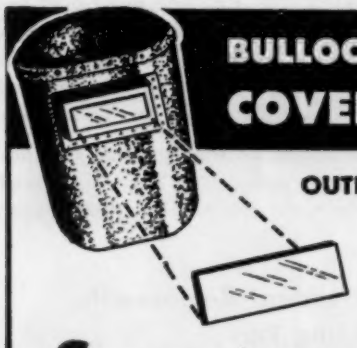
The working deck is 48 ft. wide between wing walls. Submerged, the dock has a normal draft of 23½ ft. Its draft light is about 3 ft. Because of this shallow draft, the aft flooding tanks were filled with enough water to raise the bow about 3 ft. while the vessel was being towed by a seagoing tug from the Dravo yard at Wilmington to the Erie pier at Jersey City. The 225-mile trip was made in about 30 hr.

Two vertical 12-in. I-beams are welded to the port wing wall, 75 ft. apart. These are fitted in locking devices that are fixed to the pier and serve as mooring guides.

The control house, about 13 x 3½ x 7½ ft., is built on the port wing wall. Push button controls for the six pumps used to flood and dewater the tanks are located in this house. Additional controls also are located on each pump. Two pendulum-type inclinometers are mounted on the control house, one longitudinally and one transversely.

There are six flooding tanks built in the hull. Four buoyancy compartments are formed by the two rake ends and the two wing compartment above the safety deck on the wing wall. Each of the six tanks can be flooded or dewatered independently of the others. Pumps, one for each tank, are located near the bottom of the tanks and can deliver 1100 gpm. against a differential head of 5 ft. of sea water. Each pump is direct connected by a stainless steel vertical shaft with flexible coupling to a 5-hp., 440-v., 3-phase drip-proof motor mounted on the safety deck.

Flooding ports are 10 x 37 in. inside, and are equipped with strainers. Sea cocks for flooding are 10 in. in diameter and the pump discharge sea cocks are 8 in. Flooding and discharge valves are operated



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from the control house by an hydraulic system. Provisions also are made for hand operation of each valve in emergencies.

Three 8-in. gate valves are located in the center line bulkhead between the six tanks (three on either side of the bulkhead) to equalize and pump out a flooded compartment if a pump should fail. These valves are hand operated by gear from the safety deck.

Power service for the dock is furnished through shore cable to a terminal connection box. Lighting (120 v. a. c.) is provided by connections to a 750-w./120-v., single-phase, dry-type transformer through the power distribution panel.

Ten sets of movable bilge blocks and 13 sets of keel blocks were installed on the working deck. The untreated white oak timbers that are used for these blocks were fastened together with steel dogs and held in position by welded angle clips and bolts. Sixteen sets of fixed bilge blocks, eight on each side, have been installed.

PERSONNEL

DEPPELER OPENS CONSULTING OFFICE

J. H. Deppeler, Chief Engineer of the Metal & Thermit Corp., has been granted a leave of absence to open a consulting office at 36 W. 40th St., New York City, to devote his entire attention to development of his own business as a Consulting Welding Engineer. He will retain his connection with the Metal & Thermit Corp. as consultant for that organization as well.

Mr. Deppeler's experience in the welding field extends over a 40-year period starting in the early days in the oxy-acetylene field. This experience was extended to thermit welding and during the past 15 years to every phase of arc welding.

Mr. Deppeler is a graduate of Stevens Institute of Technology, Class of 1906. He entered the employ of the Metal & Thermit Corp. in 1912 and became their chief engineer.

Mr. Deppeler is one of the founders of the AMERICAN WELDING SOCIETY and was its second president. He is still active in the affairs of the SOCIETY and is currently chairman of their Filler Metal Specifications Committee. He is also chairman of the welding committee of the A.S.M.E. Boiler Code Committee. Mr. Deppeler has been honored by the SOCIETY, having won the Samuel Wylie Miller Memorial Medal in 1944, and in the same year was made an Honorary Member of the SOCIETY. He is a Fellow of the A.S.M.E. Mr. Deppeler was primarily responsible for the development and broad applications of thermit welding and assisted greatly in the development of modern shielded arc electrodes.

CONSULTANT SERVICE FOR BRAZING OPERATIONS

After twenty years' association as a Development Engineer in the Laboratories of the General Electric Co., Pittsfield, Mass., Walter C. Reed has recently announced his retirement. Mr. Reed's outstanding achievements were his development of alloys and fluxes and methods of making joints involving metal parts. He was among the first to perfect the use of silver solder for brazing operations. General Electric has since standardized on the application of these alloys and methods in the manufacture of their finished products. Mr. Reed initiated the application of induction heating and resistance heating for silver brazing and soft soldering of joints on an automatic production basis.

In the years previous to his work with the General Electric Co., Mr. Reed developed and patented technical instruments of many types, including household labor-saving appliances, and engineered the design and production of a wide variety of acoustic apparatus.

At the present time, Mr. Reed has established a Consulting Engineering office in Dalton, Mass.

EVAN F. WILSON JOINS ATOMIC ENERGY COMMISSION

The U. S. Atomic Energy Commission recently announced the appointment of Evan Frank Wilson of Akron, Ohio, as assistant director of the Division of Raw Materials.

Mr. Wilson will be responsible for the research program of the Division of Raw Materials which is concerned principally with the development of methods of extracting uranium from low-grade domestic sources. He will have his headquarters at the Commission's New York Office of Directed Operations, 70 Columbus Ave., New York, N. Y. Prior to his appointment with A.E.C., Mr. Wilson, a metallurgical engineer, was Chief Metallurgist for the Babcock and Wilcox Co., Barberton, Ohio.

Born in Somerville, Mass., Mr. Wilson attended the University of Maine and the Massachusetts Institute of Technology from which he received his Bachelor of Science degree in 1926. He also did graduate work for two years at Carnegie Institute of Technology, Pittsburgh. Following his graduation, he worked with Jefferson Union Corp., Lockport, N. Y.; the U. S. Naval Gun Factory, Bureau of Ordnance, Washington, D. C.; the U. S. Bureau of Mines, Pittsburgh, and the Frontier Bronze Corp., Niagara Falls, N. Y.

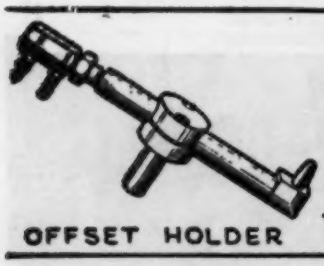
John K. Gustafson is director of the Division of Raw Materials. Other members of the Division include Jesse C. Johnson, the assistant director in charge of plant operations and the ore purchase program in the Colorado Plateau area, and Dr. Phillip L. Merritt, assistant director in charge of exploration and resources development activities and foreign ore purchases.

HESS HONORED

Prof. Wendell Frederick Hess, of Rensselaer Polytechnic Institute, will receive the 1948 Wetherill Medal of The Franklin Institute, Dr. Henry B. Allen, executive vice-president and secretary, has announced.

The medal is awarded "in consideration of his outstanding contributions to the art and science of welding, notably in the field of electric resistance welding" and will be presented to Hess by Richard T. Nalle, president of The Franklin Institute, at traditional Medal Day ceremonies in Philadelphia next October 20th.

Professor Hess was born in Troy, N. Y., on Jan. 1, 1903. He received his Doctor of Engineering degree in 1928 from the Rensselaer Polytechnic Institute and was appointed instructor in electrical engineering and physics at the Institute. He was soon advanced to the post of assistant professor and in 1937 was transferred to the department of metallurgical engineering which had recently been established. In 1938 he was made an associate professor and head


"ELECTROLOY" for RESISTANCE WELDING
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Welding Production Goes UP When AO Duraweld Goggles Go ON!

Why? Because new, specially designed side shields keep distracting light rays from welders' eyes while providing protection from sparks and splashes. Result: more and better beads! Comfort features aid work output, too—indirect ventilation reduces fogging . . . eyecups are set for wide angle vision, have comfortable, snug-fitting edges and fit the contour of each eye.

The insulated ball chain bridge and the rubber one-piece headband adjust in a jiffy. The Duraweld is prime protection in acetylene welding, cutting, brazing and furnace work. Ask for it with 50 mm. Noviweld lenses, shades 3, 4, 5, 6 or 8, or with Noviweld-Didymium lenses, shades 3, 4, 5 and 6. Cover lenses protect both types from pitting. Your nearest AO Safety Representative can supply you.

American Optical COMPANY *Safety Division*

SOUTHBRIDGE, MASSACHUSETTS
BRANCHES IN PRINCIPAL INDUSTRIAL CITIES

of the welding laboratory. In 1945 he received the rank of full professor and in 1947 became head of the department of metallurgical engineering. Professor Hess is known in the scientific world for his work on the color sensitiveness of photoelectric cells, aluminum and aluminum alloy welding, as physical photometer, filters for photoelectric cell, magnetic properties of welded materials, arc, gas and resistance welding.

The John Price Wetherill Medal is awarded for discovery or invention in the physical sciences, or for new and important combination of principles or methods already known.

SINGLETON PROMOTED

A new customer engineering service department, under the direction of Robert C. Singleton, has been established by the Nelson Stud Welding Division of Morton Gregory Corp. at its Lorain, Ohio, headquarters.

A staff of engineers and metallurgists in this department will devote their entire attention to the development of new stud welded fasteners and production units to aid manufacturing and construction firms in cutting costs through the use of stud welding. Wartime applications of this technique, originally developed to aid shipbuilding, are credited with saving more than 100,000,000 man-hours.

This expansion of customer engineering services was announced by Leonard C. Barr, vice-president of the company and general sales manager of the Stud Welding Division, in conjunction with the appointment of Singleton. He pointed out that this work—heretofore conducted largely on the west coast—is being centralized at Lorain where accessibility to the nation's chief metal working centers will facilitate speedy service.

Nelson's field engineers will continue to work directly with customers, and will be backed up by specialists in machine design, welding metallurgy and the other technical problems encountered in the development of new stud welding applications.

Singleton, who joined the stud welding organization in 1945 as field engineer and has served as its chief metallurgist and technical adviser at Lorain, will be in charge of engineers and metallurgists in the new engineering service department at the Lorain plant. He is a member of the AMERICAN WELDING SOCIETY and the American Society for Metals, and a graduate of the University of California in metallurgical engineering. Prior to joining the Nelson organization, he was metallurgical engineer with the Joshua Hendy Iron Works at Sunnyvale, Calif.

NEW LITERATURE

STRESS-STRAIN RECORDERS

Bulletin 262, a new 32-page catalog of Baldwin stress-strain recorders and strain followers, is announced by the Baldwin Locomotive Works, Testing Equipment Dept., Philadelphia 42, Pa.

The bulletin describes, with pictures and diagrams, the basic principles of the various types of Baldwin recorders; gives the distinguishing features of 24 different recorders for all common makes of testing machines; and describes more than 50 extensometers, compressometers and deflectometers that can be used with the recorders.

The bulletin also shows typical stress-strain curves as prduced by recorders, includes common testing accessories, and four types of strain gages.

CHEMICAL FORMULARY

The Chemical Formulary, Volume VIII, H. Bennett, Editor-in-Chief. Price $7.00.

Buyers of the previous volumes will welcome this new addition to the series as it contains thousands of additional, new, practical and tested formulae, some of which have never before been published.

Behind the contents of Volume VIII stand the integrity and scientific knowledge of some of America's leading industrial and research chemists. The formulae you will find here are the result of long years of research and millions of dollars spent on experiments.

This book will bring you a great fund of ideas, information, data and formulae that would otherwise be accessible only after consulting dozens of books.

It will keep you abreast of the latest developments and trends which affect all business and industry. Whatever your formulation problems may be, you are sure to find invaluable information here whether you are a chemist, engineer, executive, manufacturer or layman.

Chemical Publishing Co., Inc., 26 Court St., Brooklyn 2, N. Y.

ELEMENTARY AND APPLIED WELDING

Elementary and Applied Welding, by Herbert P. Rigsby and Chris Harold Groneman, both of the College of Texas, College Station, Texas, published by The Bruce Publishing Co., 540 N. Milwaukee St., Milwaukee, 1,, Wis. Price $2.00.

This book contains material especially adaptable to the beginning student in both oxyacetylene and arc welding. Basic procedures are given and are fully illustrated with photographs and sketches so that the learner is guided methodically from the most simple to the more complicated processes involved in the projects.

The informational material is restricted to industrial opportunities, commercial methods, tools and equipment, metals, and safety practices.

The projects, or problems, have been designed to appeal to the industrial student and to the home craftsman. Each project is illustrated by a complete job procedure. The projects include articles which will be found useful in the home, the yard, the school or home workshop, and a few miscellaneous ones.

NEWSY WELDING MAGAZINE DISTRIBUTED BY AMPCO

A quarterly magazine chock-full of information on welding with Ampco Bronze Electrodes is distributed by the Weldrod Sales Dept. of Ampco Metal, Inc., Milwaukee 4, Wis.

Called the "Ampco Welding News," the publication contains well-illustrated fact stories telling how others are using Ampco Bronze Electrodes to join and overlay various base metals. Of interest to welders is a news item in the July issue announcing that samples of Ampco-Trode 10 are being distributed without charge to any who want to try this versatile electrode for welding cast iron and iron, copper and nickel-alloys, as well as dissimilar metals. A copy of the current issue of "Ampco Welding News" will be sent free on request.

simpler!

works better!

costs less!

NCG

EVERYTHING FOR WELDING

NCG is recognized as one of the largest organizations of its kind in the world. It operates 73 manufacturing plants within the United States, offers supply and service by a vast network of hundreds of independent NCG distributors and warehouse stocks. For assured satisfaction in *your* welding and cutting needs . . .

RELY ON NCG

Torchweld is more than a line of really good flame welding and cutting apparatus—it's a factor in economics—in the economics of *your* business. You see . . . NCG knows that the test of equipment isn't completed until the product made with that equipment has satisfied *your* customers. NCG knows that the production efficiency of equipment has no real meaning until the maintenance liability of that equipment is known. NCG knows that equipment is, in the final word, an influence on *your* profits.

NCG's wisdom from 30 years' experience with the overall applications of welding in every phase of U. S. industry, is built into the Torchweld line. Torchweld may be said to have "a seasoned business man's" regard for *all* your problems.

And Torchweld pleases the man in the goggles just as much. When he uses the famous "54" Welding Torch, for instance, he recognizes instantly that the new, revolutionary "Stab-L-Flow" mixer gives him greater speed and better welds. He finds that the welding flame is truly stabilized, and that his torch doesn't pop and can't backfire.

If he uses the "75" Hand Cutting Torch he beams his astonishment at the swift ease with which it sails through steel up to 20 inches thick. He is proud of the clean, square faces and the narrow kerf. He is sure to become enthusiastic about the stainless steel head and the smooth-working diaphragm-type high pressure oxygen valve.

But these promising examples are just typical of the entire quality Torchweld line—that costs less, both initially and to use—that's simpler and works better, no matter to what task it's assigned. Send today for the new, complete Torchweld catalog that's sure to point a way to profitable improvement in *your* business.

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840 N. MICHIGAN AVE., CHICAGO 11, ILL.

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PROCEDURE FOR APPLYING FILLER METAL SHAPES

The Canadian Ramapo, Division of Joliette Steel Ltd., Niagara Falls, Ontario, has compiled a comprehensive bulletin covering the use of wear-resistant, rolled and cast nickel-manganese filler metal shapes. In general, the bulletin is designed to show the wide range of dollar-saving applications where filler metal shapes permit the economical repair of equipment and parts, the cost of which would be prohibitive in many cases, were it necessary to use weld rod deposit metal only.

Clean-cut illustrations show typical applications of the various shapes and outline repair procedure in considerable detail. Also featured is the use of nickel-manganese shapes in the welded fabrication of complete material-handling units. . .a procedure which contributes to design simplicity, making possible the construction of durable, low-cost, light-weight parts right in your own shop.

This useful bulletin (W-48A) is available on request from the above-mentioned company.

ELECTRODE BOOKLET

The Page Steel & Wire Div. of American Chain & Cable Co. Inc., Monessen, Pa., has just issued a new booklet **DH 45,** *Page Hard Surfacing Electrodes,* which consists of the following grades:

Page Special Manganese Nickel Shielded Arc Electrodes.
Page Manganese Shielded Arc Electrodes.
Page Manganese Nickel Bare Electrodes.
Page High Carbon Shielded Arc Electrodes.
Page Medium Carbon Shielded Arc Electrodes.

Each of these electrodes has been developed to provide a weld metal deposit whose particular properties are suited to definite welding applications and are outstanding in their field.

BULLETIN ON SPOT WELDING OF ALUMINUM ALLOYS

P. R. Mallory & Co., Inc., Indianapolis, Ind., announces publication of a new *Technical Information Bulletin on Spot Welding of Aluminum Alloys.*

This technical bulletin contains 36 pages printed on coated stock and is profusely illustrated with diagrams, photographs and specification charts.

There are fourteen chapters covering all phases of the spot welding of aluminum alloys, among which are sections on Surface Preparation, Equipment, Techniques and Testing of Spot Welds, and a wealth of other material, including an extremely complete Bibliography.

Requests for the Mallory *Technical Bulletin on Spot Welding of Aluminum Alloys* may be directed to P. R. Mallory & Co., Inc., 3029 E. Washington St., Indianapolis 6, Ind.

RESISTANCE WELDING ELECTRODES

A revised edition of *Ampco Bulletin 68* covering Resistance Welding Electrodes and Alloys has just been released by Ampco Metal, Inc., Milwaukee 4, Wis. The new edition has been revised throughout to present an enlarged and up-to-date listing of electrodes and accessories available. It includes newly designed water-cooled, ejector-type holders with patented features giving them many times the life of previously used holders of this type.

The increased demand by industry for resistance welding electrodes and accessories is reflected in the growing number of items listed in the book. Changing conditions have been met by new welder tips and accessories. New features have been incorporated to meet customer requirements. In every way the new bulletin emphasizes the desire of Ampco Metal, Inc., to serve the production welding field with an outstanding line of electrodes and alloys.

MACHINERY BULLETIN

A 4-page bulletin (No. 51), recently issued by the Jensen Machinery Co., Inc., of Bloomfield, N. J. describes the facilities of this organization for designing and manufacturing stainless steel custom-built equipment for all industries.

As pioneer fabricators of stainless steel whose designs and techniques are the fruit of long, comprehensive manufacturing experience, and close association with numerous applications in different fields, the company offers exceptional opportunity for obtaining special and standard types of machinery built to specification.

Bulletin 51 offers a number of illustrations showing the type of finished equipment the company is capable of manufacturing, and these provide an excellent guide for anyone contemplating acquiring mechanical units to meet special applications.

METAL JOINING HEADACHES ELIMINATED

A new 8-page bulletin, containing more than 60 illustrations, explains in simple nontechnical language, how Eutetic Welding Alloys compare with welding and brazing processes.

Stressing various methods of eliminating the usual welding headaches of distortion, stress, high temperature defects, the *Eutectic Welder Bulletin* offers every plant and shop an opportunity to select the rod designed specifically for their particular welding problem, whether it is cast iron, stainless, steel, aluminum, copper, brass, bronze, etc.

Also featured is the new cutting electrode, Cuttrode, that whizzes through all difficult-to-cut metals without the use of special equipment or oxygen. A new feature of this bulletin is the detailed instructions for use of each and every welding alloy described.

Showing more than 60 photographs of satisfactorily welded equipment and referred to as the "Illustrated Production Issue, EW-7", it may be obtained by writing to Eutectic Welding Alloys Corp., 40 Worth St., New York 13, N. Y.

STAINLESS PIPING SYSTEMS

"Taylor Forge Stainless" provides a new and more economical approach to flanged piping, which the manufacturers report to have decided advantages. Four-page, illustrated Bulletin 483 includes drawings, dimensions and prices of new type fittings and flanges, available in Stainless 304, 347, 316 and other materials. Taylor Forge & Pipe Works, P. O. Box 485, Chicago 90, Ill.

CONDENSED CHART PREPARED BY B & W ON HIGH-TEMPERATURE TUBE STEELS

The Babcock & Wilcox Tube Co. announces the publication of a new edition of its bulletin on B & W Croloys giving technical data on high-temperature steels for alloy tubes and pipe.

The bulletin offers condensed information in chart form on such factors as creep strength, short time tensile strength, oxidation and corrosion resistance, temper embrittlement and minimum physical properties. It is designed as a convenient guide showing some of the materials which are available for processing into tubes and pipe for meeting varied high-temperature requirements.

The bulletin may be obtained by writing to the Advertising Dept., Babcock & Wilcox Tube Co., 85 Liberty St., New York City.

SEAM WELDERS

An 8-page technical bulletin (Bulletin No. 804)—describing its new line of "quick follow-up" roller head seam welders which embody many new and exclusive features—has been issued by Progressive Welder Co., Detroit 12, Mich. The line comprises three basic sizes for light, medium, and heavy duty work, each size being available in three types—for circular welding, for longitudinal welding, or for both circular and longitudinal welding ("Universal" model).

Among the outstanding features listed in the bulletin are use of a head completely guided and aligned by four sets of antifriction rollers, insuring that welding wheels will follow up and down even extremely small deviations in material thickness and contour; special frame construction giving maximum strength where needed, plus complete accessibility; larger throat clearance than usual for bulky work; transformer close coupled to welding arms to reduce current loss; and specially developed copper alloys for maximum strength where strength is needed.

Used either for continuous, water or gas tight seam welding, or for roll-spot welding, these machines function equally well when welding cold rolled, stainless, and various alloy steels; aluminum and other non-ferrous metals; and various types of coated metals.

Important points of design and operations of the welders are made plain with text, closeup photographs, and labeled drawings. Numerous special Progressive seam welders are also pictured.

They Take "Roughing Up" And Really Like It!

SMITHway A.C. WELDERS

LOWER COSTS, STEP UP OUTPUT!

SMITHway Welders stand up under heavy production service that punishes other welding machines. Built-in surplus strength and extra power mean the difference between failure and performance . . . at a time when you need a welder that will perform.

The complete line of SMITHway A. C. Welders includes general-purpose models rated at 150, 200, and 300 amperes; heavy-duty models rated at 300, 400, and 500 amperes; limited input utility welder, 180 amperes, operates on 230-volt A. C. power.

SMITHway *Certified* ELECTRODES

made BY welders ... FOR welders

A. O. Smith originated modern heavy coated electrodes and modern welding techniques. Proof of SMITHway Electrodes has been given repeatedly in their huge production record. More than 320,000 have been used *daily* in A. O. Smith plants ... millions more, by other manufacturers.

Sold by Distributors Everywhere

There is a SMITHway A. C. Welder specially designed to do your job—and do it *better* at less cost. Half a century of welding experience in A. O. Smith's own plants is embodied in the tough excellence of these precision-built machines. Rugged, trouble-free, accurate, safe—they speed output and cut costs. For all the facts, send the coupon—now!

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A. O. SMITH Corp., Dept. WJ-948, Milwaukee 1, Wis.

Without obligation, send us complete information on:

☐ SMITHway Heavy-Duty A.C. Welders ☐ SMITHway General-Purpose A.C. Welders
☐ SMITHway Limited Input Utility Welder ☐ SMITHway *Certified* Electrode Catalog

Name_____ Firm_____

Street_____ City_____ State_____

NEW PRODUCTS

The Society assumes no responsibility for the validity of claims in this section

SILICON BRONZE ELECTRODE

The Air Reduction Sales Co. has announced the immediate availability of the new Silicon Bronze Electrode. According to the manufacturer these electrodes may be used for the welding of silicon bronze base metal, copper and for joining galvanized iron and silicon bronze to steel. It is believed that this new electrode will find wide acceptance in the manufacture of chemical and food processing equipment, sewer disposal equipment and hot water tanks. According to Air Reduction their new Silicon Bronze Electrode offers the following advantages:

1. Soft, spray type, shielded arc action.
2. Very low spatter loss.
3. Exceptional free flowing, dense deposit.
4. Very easy slag removal.
5. Crack-free welds.
6. Unusually smooth deposits.
7. All position welding.
8. Ability to weld silicon bronze, copper, iron base and dissimilar metals.

The new Airco Silicon Bronze Electode is available in 5 diam. ranging from $^3/_{32}$ to $^1/_4$ in. and varying in length from 11 to 18 in. The new electrode may be purchased in standard 50-lb. packages. If you would like a free demonstration of this new electrode in your own welding shop write the Airco Sales Office nearest you.

FLUX RECOVERY EQUIPMENT

Invincible Vacuum Cleaner Mfg. Co., Dover, Ohio, has prepared a new folder describing their Flux Recovery Equipment for submerged arc welding. This folder fully describes the benefits of such equipment, basic feature of design, models available, and typical installations.

Because of the growth of submerged arc welding, Invincible Flux Recovery Equipment is finding an ever-growing market.

WELDING LENS

The American Agile Corp. of Cleveland, Ohio, announces its new, improved Agile Metalklad Welding Lens. These lenses, due to their high light reflection and absorption qualities eliminate arc glare, increase welding efficiency from 15 to 50%, increase visibility 42% and afford 100% more eye protection. These features are possible because a new hard and durable alloy of high reflectivity is now being used for the coating. The basic dark welding lens is clad with this coating on the outside surface, achieving a hard, transparent, mirror-like surface which completely reflects ultraviolet and infrared rays given off by the electric arc. The repelling of these rays decreases eye fatigue and eye strain of the welding operator. Metalklad lenses are now in mass production and are available in any quantity. For additional information and prices, write to the American Agile Corp., 5806 Hough Ave., Cleveland 3, Ohio.

X-RAY DIFFRACTION

Broad, new fields of application for X-ray diffraction in the identification and quantitative analysis of unknown materials have been opened by a high-precision, high-output machine revealed for the first time this week by General Electric X-Ray Corp., Milwaukee, Wis., a G-E affiliate.

The unit, with its many attachments, was shown in an exhibit, and described in two papers read before the International Congress of Crystallography held July 28th to August 3rd at the Harvard University Department of Mineralogy.

One attachment, the fluorescent analyzer, greatly extends the range of composition of materials which can be analyzed, in comparison with that possible when using optical spectrometers.

Another group of attachments, which make possible the direct recording of X-ray intensities on a continuous strip of chart paper, save countless hours of laboratory time by revealing both the angular placement of the characteristic lines of materials and their relative intensities.

The new unit couples, for the first time, precision control of X-ray output with high X-ray intensity. Hitherto, such accuracy could be achieved only at the expense of intensity. This was reflected in the comparatively low milliamperage at which such machines were operated. Now, accurately controlled X-ray diffraction beams of higher intensity can be produced. The tube can be operated at milliamperages up to 30.

The new instrument may be used, with different attachments, for three different purposes:

One of these is for the direct measurement of X-ray diffraction intensities through the use of a Geiger-Müller counter in combination with a rate meter, scaler and chart recorder. The counter is capable of counting diffracted X-ray quanta lineally over a longer range of intensities than ever before possible. The rate meter, which is matched with the strip chart recorder, has a logarithmic response over three decades.

The second manner in which the unit may be used is as a fluorescent X-ray spectrometer, employing a focusing crystal analyzer.

Third, it may be employed, with X-ray-sensitive film, as a conventional X-ray diffraction unit.

Of particular significance is the radical departure in external design. All apparatus except the chart recorder is incorporated into an attractive desk-type console, with the top free from obstructions around and under the tube. The tube mounting permits quick and accurate change of X-ray tubes. Either the direct-recording apparatus or the fluorescent analyzer can be used simultaneously with the precision track for conventional diffraction radiographic cameras.

The X-ray quanta count scaler is used to measure the time required to produce a pre-selected number of counts so that probable accuracies within 2, $1^1/_2$, 1, $^3/_4$ and $^1/_2$% can be pre-selected. This permits scaling high X-ray intensities without concern for the limitation of a mechanical impulse counter, produces data of uniform probable accuracy and minimizes the time spent in collecting data.

A self-contained X-ray tube cooling system eliminates plumbing and operational difficulties associated with conventional tap-water systems.

TIP CLEANER DEVICE

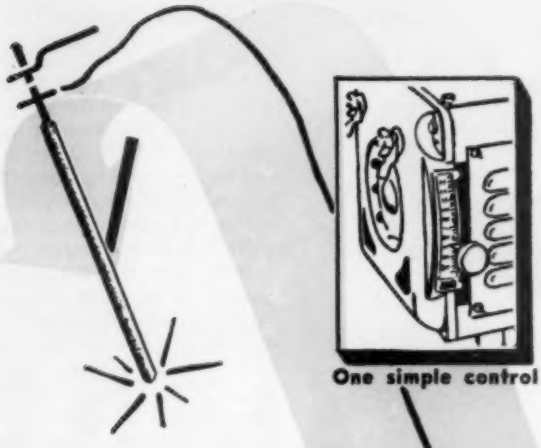
Those who use welding equipment will be happy to know of the development of a new Tip Drill Kit, manufactured by the J. M. Ragle Industries of Kansas City, Mo.

The kit is approximately the size of an automatic pencil, and is designed with pocket clip so that it can be carried in the pocket mush in the same manner as a pencil.

The end is a tempered steel double-end chuck holding drill sizes 45–80. The handle holds 24 different size drills. Twelve assorted drills in even number sizes 52–74, inclusive, are supplied with the kit.

Since this tip-cleaning tool actually uses carbon steel drills, most every welding tip can be cleaned and reconditioned in a matter of a minute or two.

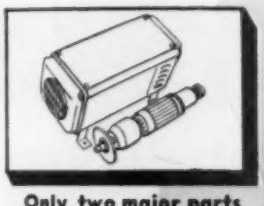
The kit retails at $3.50, and is available at most welding equipment dealers.



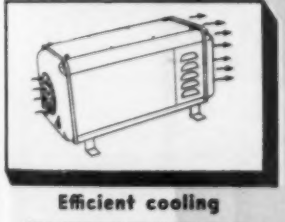
One simple control

Turn the Heat *on production*

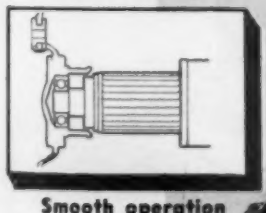
DC arc-welder users: Standardize on dependable P&H WA-200 machines—for faster work, lower costs



Only two major parts



Efficient cooling



Smooth operation

It is heat at the end of your electrodes that speeds welding, reduces costs. And, it's the ability of P&H WA-200 DC arc welders to produce this heat — hour after hour — that maintains stepped-up production schedules.

So, if you use DC arc welding machines, here are a few reasons why it pays you to turn the heat on production with WA-200's:

Simplified control speeds and improves the work — Operators obtain any desired welding current with one simple control. Volt-ampere regulation is automatic — there is no fussing with dials, gadgets, or special instruments. Your operators save time because it is so easy to select exactly the right welding heat. The work improves — welds are sounder and better-looking.

More flexible service reduces your welding equipment investment — Square frame design permits stacking of machines. Units can be cut in and out of parallel, providing a more flexible service and a much wider welding range. When stacked for multiple service, a simple paralleling switch quickly provides service for one or two operators. *No other welder offers this advantage.*

Sturdy construction — There are only two major parts in a WA-200 — the rigid one-piece frame and a husky rotating member. The frame prevents misalignment and eliminates vibration, making possible long continuous operation.

Dynamically balanced rotating member — is mounted in large grease-lubricated ball bearings. You benefit from smoother, quieter operation, high mechanical efficiency, minimum maintenance requirements, and longer life.

Efficient cooling — a large multiple-blade fan forces a constant stream of air through the machine. Destructive heat is removed, insulation stands up, and trouble-free operation is assured.

WA-200's have a welding service range from 30 to 285 amps per single unit. Less than 3½ square feet of floor space accommodates this compact welder.

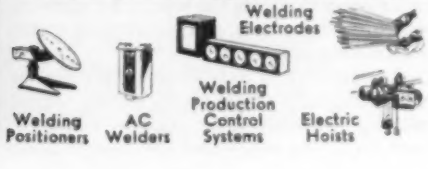
Let your P&H representative or distributor show you why WA-200's get your work out faster and save production time and money. Write us for latest bulletin W34-4.

P&H

ARC WELDERS

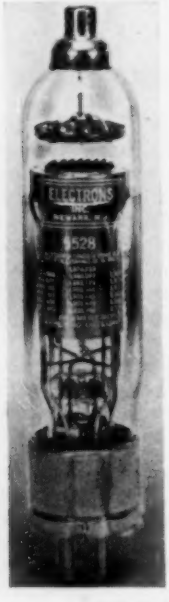
4551 West National Avenue
Milwaukee 14, Wisconsin

HARNISCHFEGER CORPORATION



RECTIFIER TUBE

Electons, Inc., 127 Sussex Ave., Newark, N. J., announce the development of a fast deionizing, temperature-free, grid controlled rectifier tube type 5528 (C6L).



This tube is designed especially for high power servo motor control or inverter applications which must operate at up to 800 cycles, and where utmost reliability and stable characteristics are required over wide ambient temperature ranges.

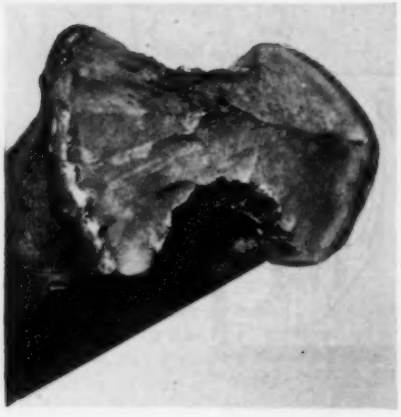
Pertinent electrical characteristics are: 60-sec. heating time; 500 peak inverse volts; 6.4-amp. steady D.-C. current and 77 peak amp.

HARD-SURFACING ELECTRODES

To extend its complete line of hard-facing electrodes The Lincoln Electric Co., Cleveland, Ohio, is now producing two new electrodes of the coated tubular type for depositing super-abrasion resisting surfaces of weld metal. Tubular electrodes are steel tubes in which is contained the hard-surfacing alloy in a concentrated form. The alloy is deposited into the molten crater where it is either bonded into a tough iron alloy matrix or alloyed by the heat of the arc with the base metal to create the final hard-surfacing alloy. This type of rod gives a higher consistency of hard-surfacing alloy at a lower cost than is possible with the cast rod.

Tungweld-C is a tubular, light coated electrode which contains in the tube *coarse* particles of tungsten carbide. The particles are deposited by the arc in the weld crater and as the weld solidifies are held in a tough iron alloy matrix. The result is a weld deposit superior to all other types of deposits in resisting abrasion. When the edge of the deposit is subjected to abrasive wear, the iron alloy and the base metal wear away exposing the teeth-like particles of tungsten carbide, thus producing a self-sharpening edge.

Tungweld-C is recommended for use for surfacing earth cutting tools when a jagged rough, self-sharpening edge is required, and for facing other tool surfaces to resist



extremely severe abrasion. A churn bit that had been surfaced with Tungweld-C drilled through sand, shale and gravel 900% further than bits that had not been hard faced. Scraper blades, dipper teeth, oil well drilling bits, muller plows scarifier teeth when hard faced with Tungweld-C all have greatly increased performance life under the toughest of service conditions, thus saving hours normally lost in downtime.

Tungweld-F is a shielded arc tubular electrode containing *fine* particles of tungsten carbide. It is for use on earth cutting tools but produces a smoother, thinner and sharper edge than the rough edge of Tungweld-C. The tungsten carbide particles are so small that they will not stick out like teeth as do the coarser particles, and are so close together that they are not undermined by the abrasion of a blast of muddy sand. Tungweld-F is used for tools that cut material such as cane, ensilage, for mixing blades, dredge cutter blades, coal cutter bits, tool joints, post hole augers and pug mill knives and augers.

Tungweld-C and Tungweld-F are available in 14 in. length in $^1/_4$ in. size, packed in 5-lb. containers.

The water well drilling cable tool bit illustrated herewith, is a typical hard surfacing application for superabrasion resisting Tungweld. Depending upon the material through which the bit is drilling, either Tungweld-C or Tungweld-F may be applied to the outside edge of the bit. This particular bit drilled 278 ft. or 900% deeper than the normal hot forged bits before needing refacing again.

AIR REDUCTION ADDS SOAPSTONES TO SUPPLY LINE

In response to increasing demands for the item the Air Reduction Sales Co. has announced the addition of soapstones to their complete line of welding supplies.

Soapstones, also referred to as Talc Crayons, have many uses in the metal-working field. Oxyacetylene burners use them for sketching the contour of shapes to be cut. Welders use them to mark lap joints and stock handlers find soapstones a necessary item for the marking of sheet metal to be stocked.

Air Reduction will market a $^3/_{16}$- x $^1/_2$- x 5-in. long soapstone, packaged one gross to a carton. Unless specified on an order for other materials these soapstones will be sold in a minimum quantity of six.

SAMPLE ELECTRODES OFFERED BY AMPCO

Ampco Metal, Inc., Milwaukee 4, Wis., is offering to send without charge to welders, three sample rods of Ampco-Trode 10 aluminum bronze electrodes so that the welder can prove for himself the versatility of this bronze rod which will weld cast iron, and iron copper- and nickel-base alloys as well as dissimilar metals.

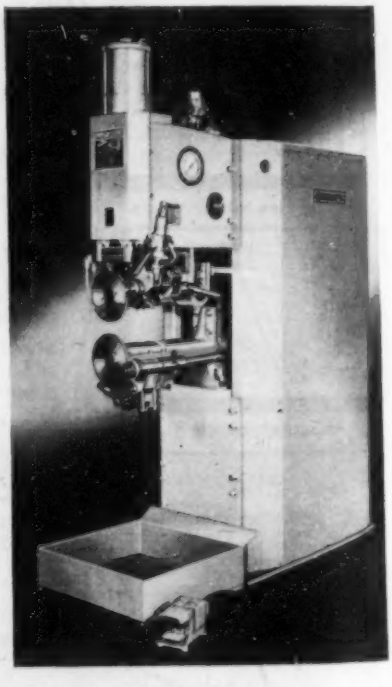
Heretofore the welder had to stock a number of specialty rods to weld various base metals but by using Ampco-Trode 10 excessive inventories are eliminated.

The welder has a choice of diameters, $^3/_{32}$, $^1/_8$, $^5/_{32}$ or $^3/_{16}$ in., but only one diameter rod will be given on this free offer.

Those interested are invited to write to Ampco Metal, Inc., Milwaukee 4, Wis.

SEAM WELDERS

A complete new line of roller-head seam welders embodying many new and exclusive features has been announced by Progressive Welder Co., 3050 E. Outer Drive, Detroit 12. The line comprises three basic sizes—light, medium and heavy duty. Each size is available in three types—for circular welding, for longitudinal welding or for both circular and longitudinal welding ("Universal" models).



Among the outstanding features of the new line is the use of a head completely guided and aligned by four sets of antifriction rollers, insuring that the welding wheels will follow up and down even extremely small deviations in material thickness and contour. As a result it is possible to maintain constant weld pressures even where stock thickness varies along the seam, assuring consistent even weld characteristics.

The rollers are matched in pairs, adjustable preloaded, and guide the head the full length of its vertical travel, riding on positive alignment V-guides on hardened and precision ground ways.

Alloy Steel has assumed such a tremendous role of such primary importance in so many essential industries, that the American Society for Metals welcomes this opportunity to dedicate as the theme of the 30th National Metal Congress & Exposition — "A Salute to Alloy Steel".

Alloy Steel is a truly American achievement. Since the tremendous improvement in Alloy Steel during the past 30 years has paralleled the growth and importance of the American Society for Metals, it is fitting that the 20,000 members of this society, who represent the Alloy Steel producing and consuming industries, should sponsor this well-deserved tribute.

BRILLIANT TECHNICAL PROGRAM

A vast panorama of progress in Alloy Steel production and fabrication will be presented at the Philadelphia Metal Congress & Exposition. A brilliant program of over 100 stimulating and helpful technical papers on all aspects of Alloy Steel will be presented by recognized authorities at the Metal Congress.

DISTINGUISHED SERVICE AWARDS

An outstanding feature of this diamond jubilee of Alloy Steel will be the presentation of "Distinguished Service Awards" to individuals who, by research, improved manufacturing processes, experimentation, new applications and various other means, have contributed to the improvement, development and acceptance of Alloy Steel. Nominations for these awards will come from the entire metal industry and will be judged by a special Awards Committee of top-ranking executives.

THE DRAMA OF ALLOY STEEL

Along with the distinguished displays of over 350 manufacturers and processors of metals and metal products will be a spectacular dramatization of the 75 years progress in Alloy Steel. Occupying the entire stage of Convention Hall, this exhibit will give visitors to the Exposition the complete story of Alloy Steel.

From all over the nation, metal men are making plans to come to Philadelphia for this great jubilee. Don't miss it—make your arrangements TODAY!

Sponsored by the American Society for Metals in co-operation with the American Welding Society, the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers, and the Society for Non-Destructive Testing.

MANY LEADING FIRMS ARE EXHIBITING
SOME CHOICE SPACES STILL AVAILABLE

WRITE OR WIRE COLLECT
W. H. Eisenman, Managing Director
National Metal Exposition
7301 Euclid Avenue—Cleveland 3, Ohio
UTah 1-0200

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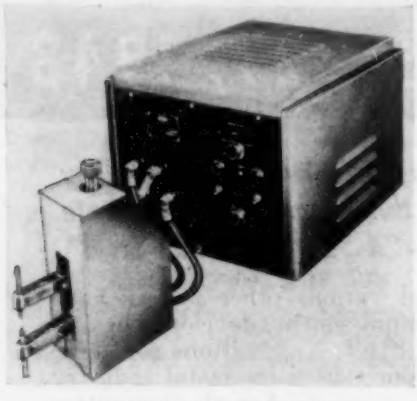
This construction has been made successful by the frame design of the new machines. Instead of having a fairly uniform cross section, the front of the machine column is extremely rigid and well braced, while the rear of the column—where there are negligible stresses—is of fairly light construction designed to provide maximum accessibility to all components inside the machines.

The seam welders may be used either for continuous, water- or gas-tight seam welding, or for roll-spot welding and may be used for cold-rolled steel, stainless or other alloy steels, aluminum and other nonferrous alloys as well as various types of coated metals.

CONDENSER WELDPOWER

Raytheon Manufacturing Co., Waltham, Mass., has announced the release of a new model of the Freshman 200 M.F.D. Condenser Weldpower.

The Freshman is designed for high-speed precision welding of both ferrous and nonferrous metals and is particularly applicable in industries which manufacture radio tubes, jewelry, aircraft, telephone, surgical and optical equipment as well as electrical parts, switches, radio parts and small fabricated metal parts.



Easy to install and operate, the weldpower unit is electronically controlled and operates from a 115-v. lighting circuit. It delivers a high current at low voltage to the welding electrodes and provides a precise amount of energy to the weld. The level of energy delivered by the unit is adjustable over a wide range—from 3.5 to 63 watt-seconds. The weldpower is ready to operate when plugged into a standard 115-v., 60-cycle lighting circuit, connected to the welding head and adjusted to the desired level of energy.

The unit is ideal for welding metals of high thermal conductivity such as aluminum, copper and phosphor-bronze which require precision welding methods. Conventional welding equipment demands a power source of high capacity to develop the currents necessary to weld such metals, whereas weldpower units work on the stored energy principle. Energy is accumulated and stored for each weld operation in the interval between welds. The energy delivered to the welding head greatly exceeds the instantaneous demand on the 115-v. power source. Thus the necessity of expensive power lines, having high current capacities, is eliminated and extra savings are obtained where charges for power are based on peak loads.

A bulletin describing the Freshman Condenser Weldpower is available and may be obtained from Raytheon's Product Information Office, Waltham 54, Mass. Literature is also available on larger and smaller Raytheon electronic welding equipments.

COMBINATION WELDER CONTROLLER

The new Class 8992 Type BBG-1 combination controller developed by the Square D Co., Milwaukee, Wis., provides complete electrical control for a small foot or motor operated resistance welding machine. The single enclosure contains a N.E.M.A. 1A pneumatic weld timer, a size 1W, 100-amp., high-speed magnetic welder contactor and a control transformer.

For operator safety the initiating switch and control circuits operate at 110 v. isolated from the power supply. The timer is mounted on a *Safront* swingout panel with the adjusting dial on the front and all energized parts in the rear.

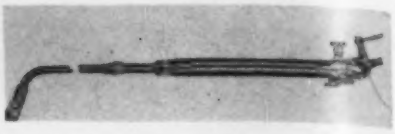
Controllers are designed to permit either common or separate control supply connections. A dual primary control transformer may be connected for 110, 220 or 440 v., 60 cycles or for 380 v., 50 cycles.

Combining the timer and contactor in a single unit with all interwiring provided greatly reduces cost of material and labor required for installation. Rugged construction and simplicity of operation make this unit ideal for small shops. For complete details, address Square D Co., 4041 N. Richards St., Milwaukee 12, Wis.

WELDING AND HEATING TORCH

Now in production by Weldit, Inc., is their Model 160 and 160-G, super welding and heating torch. This is a 3-hose torch, using two tanks of acetylene and one of oxygen. It is of particular advantage in welding, heating or brazing broken parts on heavy machinery, expanding tie rods, for heavy press installations, for bending large diameter pipes and wherever rugged maintenance work is needed.

A particular feature of the 160 torch is the quick operating oxygen cut-off which instantly and automatically shuts off the oxygen supply. The torch is also supplied with 2-valve control for using propane, natural or manufactured gas and oxygen for heating purposes.



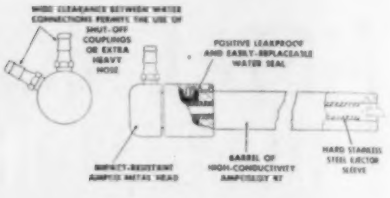
The torch has a sturdy brass handle and Monel tip-tube. The over-all length is 51 in., weight is 6 lb., 12 oz. Can be furnished for welding or with multiple-flame tips for heating.

The Model 160 torch is now in use by a number of large industrial users, including various General Motors units and Ford of Canada.

Further information and prices may be obtained from Weldit, Inc., 990 Oakman Blvd., Detroit 6, Mich.

WATER-COOLED EJECTOR-TYPE HOLDER FOR SPOT WELDER TIPS

A newly designed water-cooled ejector-type holder for spot welder tip has just been announced by the Resistance Welding Dept. of Ampco Metal, Inc., Milwaukee 4, Wis.



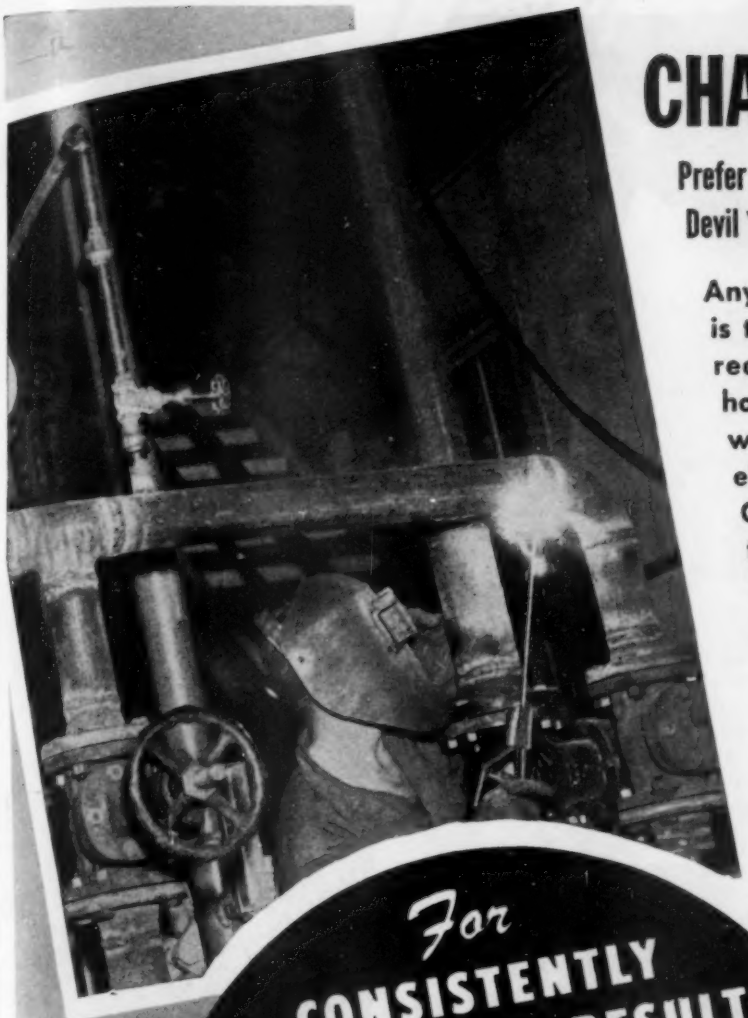
The new holder has proved under practical operating conditions to be trouble-free. Welder tips are ejected easily with a light tap on the head, allowing quick replacement.

A feature of the new holder is a positive leak-proof and easily replaceable water seal of Sirvene rubber. The head is of impact-resistant Ampco Metal, an aluminum-bronze alloy. The ejector sleeve is stainless steel and the barrel is constructed of Ampcoloy 97, a high conductivity alloy. Water connections are set at an angle with sufficient clearance to permit the use of shut-off couplings or extra heavy hose.

SCALING HAMMER

The Rotor Tool Co., 17325 Euclid Ave., Cleveland 12, Ohio, announces a new S-1 Scaling Hammer with Lever Throttle for the following applications: weld flux scaling, weld spatter removal, paint scaling, rust removal, etc.

The new tool, as shown, has a lever throttle so that the tool can be held and operated in one hand. This is a convenience for such operations as welding, where operator holds the welding electro in one hand, and is also convenient for reaching into recesses for rapid removal of weld flux scaling. The lever throttle is designed so that light pressure on the lever meters sufficient air for light work, heavier pressure gives full power. The other features of the tool, such as the exhaust air cleaning the work of chips and scale, chisel retainer with easy removal by thumb pressure, and the wafer valve of stainless steel are the



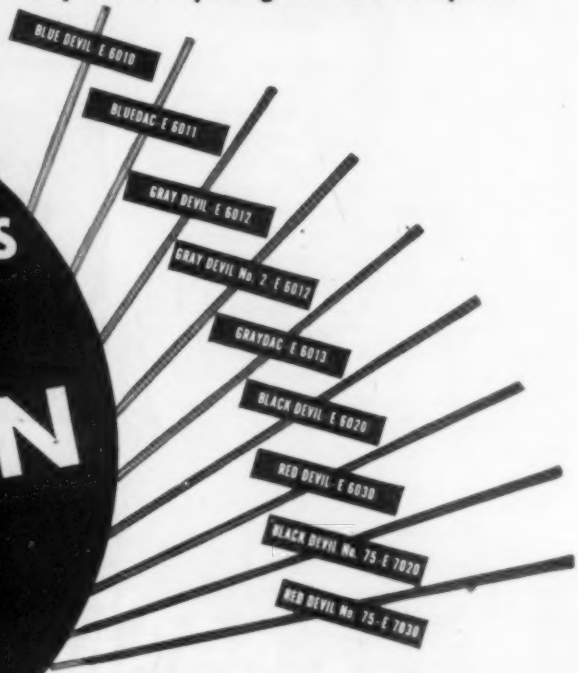
CHAMPION WELDERS

Prefer Champion's Blue Devil (AWS E6010) or Blue Devil "85" (AWS E7010) Electrodes for Welding Pipe

Any operator will tell you how difficult it is to weld pipe—especially when the job requires flat, vertical, overhead and horizontal welding. That's why veteran welders insist on the best all position electrodes obtainable and greatly favor Champion's Blue Devil electrodes for this particular application. Photo shows an operator welding 2-1/2", 3" and 4" pipe and using 5/32" electrodes.

To obtain welds of champion calibre, select CHAMPION WELDING ELECTRODES—they are everything the name implies.

For
CONSISTENTLY OUTSTANDING RESULTS
Use
CHAMPION Welding Electrodes!


BLUE DEVIL E 6010
BLUEDAC E 6011
GRAY DEVIL E 6012
GRAY DEVIL No. 2 E 6012
GRAYDAC E 6013
BLACK DEVIL E 6020
RED DEVIL E 6030
BLACK DEVIL No. 75 E 7020
RED DEVIL No. 75 E 7030

A "Team" of CHAMPIONS covers every welding requirement. Send for bulletin describing each electrode and its application.

CHAMPION Electrodes are Weld Rated Electrodes

THE CHAMPION RIVET COMPANY

CLEVELAND, OHIO — **EAST CHICAGO, IND.**

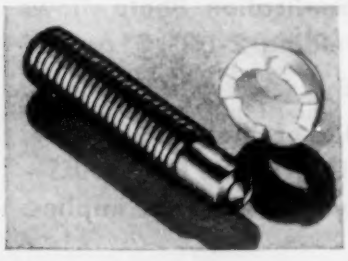
UNIVERSITY OF MICHIGAN LIBRARIES

same as the S-1 Scaler with push throttle control.

Chisels are furnished in blanks—flats and spoon shapes, and a full line of star drills is available in sizes of $^3/_{16}$ to $^3/_4$ in.

ARC WELDING STUDS

A new bulletin has been released by KSM Products, Inc., Merchantville, N. J., which describes fully the arc welding studs and arc shields manufactured by the company for a wide variety of industrial applications.



Standard studs, available from stock in sizes from $^1/_4$ in.—20 x $^3/_4$ in. to 3 in. long, to and including $^1/_2$ in.—13 x 1 in. to $3^1/_2$ in. long in increments of $^1/_4$ in. in length and $^1/_{16}$ in. in diameter, are described with design and construction details clearly shown. Also included are chemical analysis and physical properties of steel used, fluxing method employed, minimum fillet diameters, and thread strength.

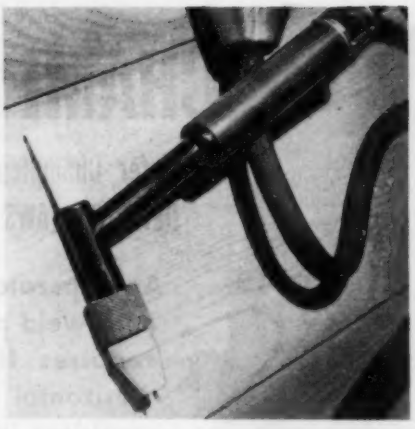
Special studs without threads, large sizes, collar studs, welding pads, headed studs, and others with S.A.E. threads are illustrated and discussed.

A copy of Bulletin P-7 will be sent upon request to KSM Products, Inc., 6512 Park Ave., Merchantville, N. J.

HELIWELD HOLDERS

An important advancement in the commercial adoption of inert-gas-shielded arc welding has been made possible by the development of new manual equipment for production line service. Air Reduction's Airco Manual Heliweld Holders provide a heavy-duty, water-cooled holder ideally suited for production work but equally suited for any general purpose jobs within the range of inert-gas-shielded arc welding.

The exterior of the holder itself is all-plastic, providing insulation against both the welding current and the high-frequency current required for arc-starting and arc-stabilization. The plastic used is ethyl cellulose, an extremely tough and rugged material with exceptionally high-impact strength and good moisture resistance. Its light weight makes possible a heavy-duty tool weighing only 28 oz. . .can be handled without tiring over long periods. The built-in water-circulating system, which extends almost to the point where the electrode is gripped, prevents overheating during prolonged use.

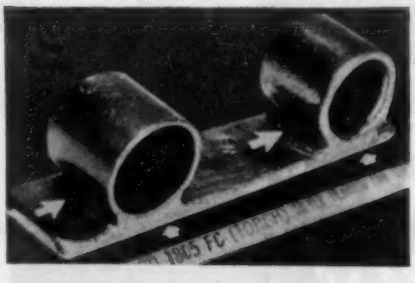


Manufactured by Air Reduction, New York 17, N. Y.

BRAZING ROD FOR COPPER

A new development in the field of torch welding rods is announced by Eutectic Welding Alloys Corp., New York.

Eutecrod 1805FC is recommended for a broad number of production applications called for in the joining of copper. It may be used with a torch adjusted for slight oxidizing flame, atomic hydrogen or twin carbon arc, where no oxyacetylene equipment is available.



Eutecrod 1805FC is a thin-flowing, low-melting, brazing-type alloy with an unusually high-tensile strength of 90,000 psi. and a Brinell hardness of 160–180. It is available in sizes $^1/_4$, $^3/_{16}$, $^3/_{32}$ and $^1/_8$ in. flux coated and in size $^1/_{16}$ in. bare. It is designed particularly for oil refinery equipment, piping and fittings, roofing repair, copper tanks and tubing, copper valves and vats, copper kettles, heating apparatus, etc.

For detailed information write to Eutectic Welding Alloys Corp., 40 Worth St., New York 13, N. Y.

FIELD OFFICE

A new use for Dravo shipping containers is pictured here. This unit was transformed into a temporary field office on a construction job in eastern Pennsylvania merely by furnishing it and installing telephone and electric light. By using the portable, weathertight container, the cost of building—and dismantling—a temporary wooden structure on the job site was eliminated. Moreover, the steel container is fire resistant, providing safer storage for blueprints and records, and may be shipped intact from job to job, either by truck or rail. Dravo containers, designed

primarily to prevent pilferage and facilitate material handling in marine and rail transportation of many different kinds of cargo, also are being used as portable tool sheds on construction projects.

HAND SHIELD

A new lightweight, seamless welding hand shield is announced by American Optical Co., Southbridge, Mass.

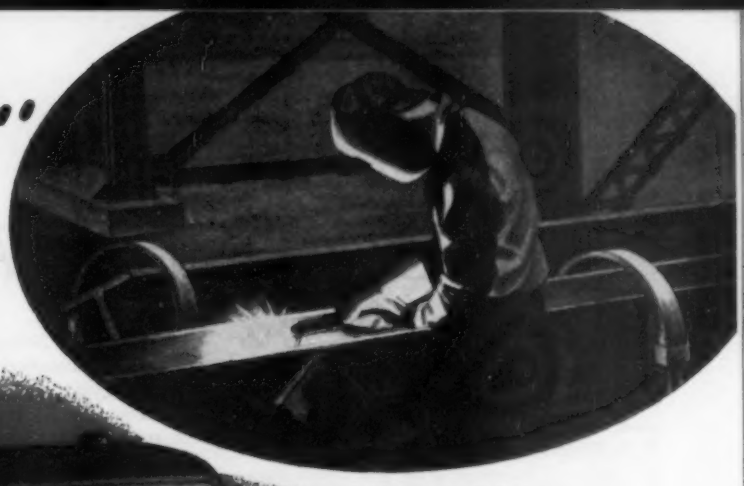
Recommended on operations where a welding helmet is not practical and on tack welding and set-up work, the small, compact shield is entirely seamless—made in one piece from special fiber.

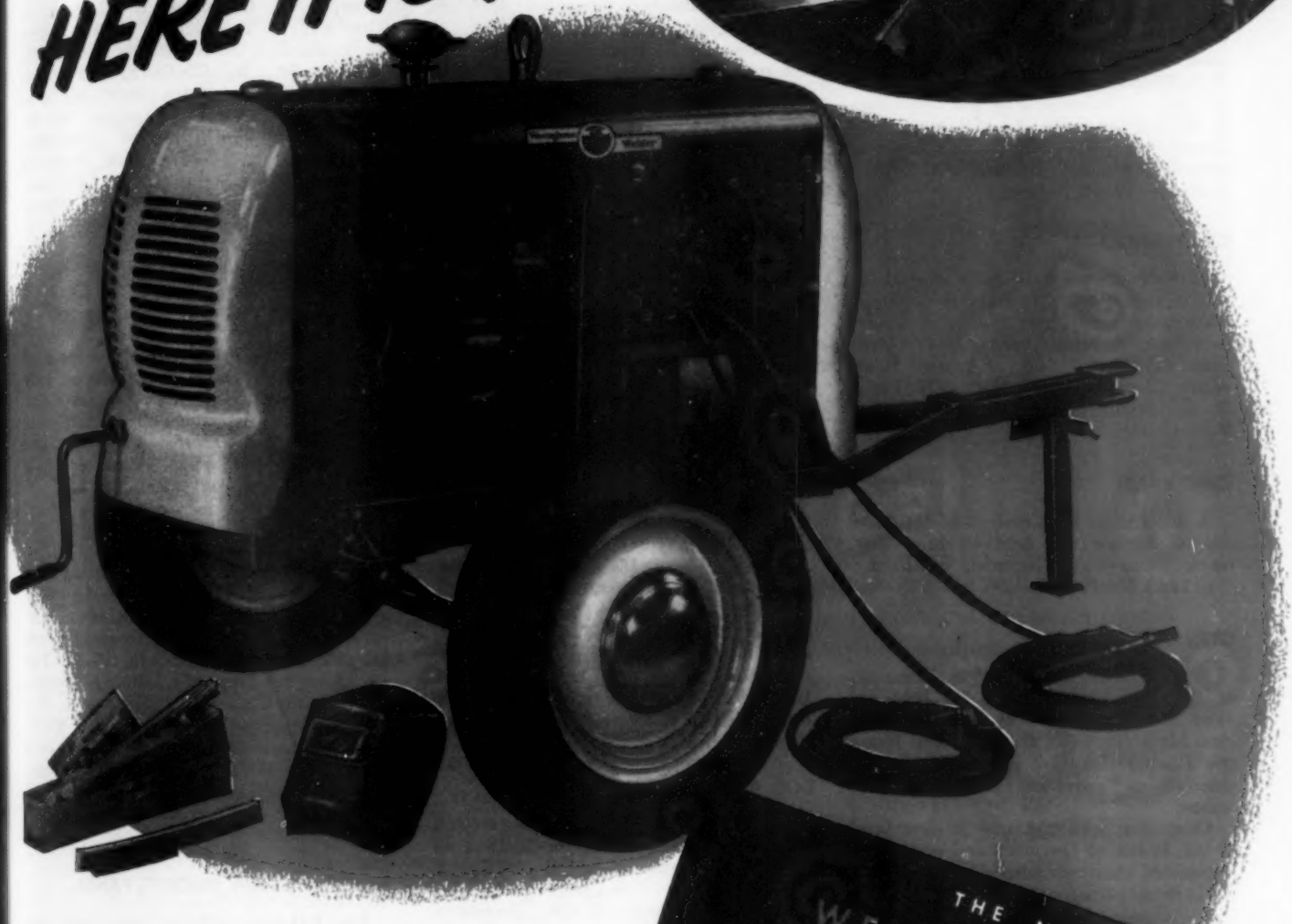
The steel welding glass holder of the shield is insulated and rivetless. The fiber handle is $5^1/_2$ in. long, is securely riveted to the body. Without glass, the entire shield weighs only 11 oz.

The new welding hand shield is available with standard Noviweld or Filterweld glass plates which insure eye protection against welding hazards.

ANNUAL MEETING
American Welding Society
Bellevue Stratford Hotel
Philadelphia Oct. 24-29

They asked for it... HERE IT IS!





e men who supervise construction in hard-to-get-at ots asked for it . . . and wrote the specifications for it. estinghouse produced it—a rugged, lightweight welder rugged terrain. One that can go to work anywhere, time . . . where electric power is not easily available. The new Westinghouse engine-driven welder on wheels smaller, lighter, but with big-welder stamina. Powered a four-cylinder, 1800 rpm, Hercules industrial engine, Ranger is designed and built to NEMA standards . . . a rating of 200 amps, 30 volts, 50% duty cycle, with elding current range of 20 to 250 amperes. This wide ge of welding current adjustment is divided over four erlapping ranges, in each of which stepless current justment is obtained by rheostatic control.

Easily transportable on 2-wheel, spring-mounted pneutic-tired, standard road gauge running gear for road ving *at high speed*. Also available without running gear stationary mounting.

Here's the welder you've been asking for—built for rd, continuous use on any kind of job. Welder comes mplete, with all essential accessories, for immediate lding service. For full details, write Westinghouse ctric Corporation, P. O. Box 2025, Buffalo 5, N. Y.

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THE NEW WESTINGHOUSE

FLEXARC RANGER

ENGINE-DRIVEN WELDER

- LIGHT WEIGHT
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- STEPLESS CURRENT ADJUSTMENT
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- WELDS ANYWHERE—ANYTIME

Westinghouse

PLANTS IN 25 CITIES . . . OFFICES EVERYWHERE

WELDERS AND ELECTRODES

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SECTION ACTIVITIES

BIRMINGHAM

1948–49 officers have been elected by the Birmingham Section as follows: *Chairman*, Lloyd C. Stiles; *Vice-Chairman*, R. L. Williams; *Secretary-Treasurer*, Don H. Curry; *Chairman, Program Committee*, A. E. Pearson; *Chairman, Arrangements Committee*, J. Thompson Vann; *Chairman, Membership Committee and Reactivation Committee*, W.B. Browing.

CHATTANOOGA

1948–49 officers have been elected by the Chattanooga Section as follows: *Chairman*, Louis Chambliss; *Vice Chairman*, Jack von Schaaf; *Secretary-Treasurer* John W. Kelker, Jr.; *Executive Committee*, Clarence Miller, Horace H. Peek, R. E. Lorentz, Jr., J. F. McElwee and P. O. Leach.

CINCINNATI

A fish fry for all members of the Cincinnati Section was held on May 21st on the Farm of the Cincinnati Ventilating Co., Duck Head, Ky.

CLEVELAND

The first meeting of the 1948–49 season of the Cleveland Section was held on June 28th at Browns Cottage, and Chairman M. S. Shane, of the Cleveland Electric Illuminating Co., outlined a heavy schedule of activities for the coming season.

Altogether approximately 30 members of the Board of Directors and operating committee chairmen turned out to work out in detail plans for the coming year.

DETROIT

The following officers have been elected by the Detroit Section to serve for the fiscal year beginning June 1, 1948: *Chairman*, J. R. Stitt, R. C. Mahon Co., Detroit; *1st Vice-Chairman*, T. J. Crawford, Consulting Engineer, Berkley; *2nd Vice-Chairman*, E. B. Brown, American Brass Co., Detroit; *Secretary-Treasurer*, Keith Sheren, Swift Electric Welder Co., Detroit; *Assistant Secretary*, L. A. Strobel, Detroit Edison Co., Detroit.

The following officers have been elected by the Saginaw Valley Division: *Chairman*, Roscoe M. Wheeler, A. C. Spark Plug Division, GMC, Flint; *Vice-Chairman*, R. Koehler, Resistance Welder Corp., Bay City; *Secretary-Treasurer*, Irving C. Mattson, Dow Chemical Co., Midland.

KANSAS CITY

The following officers have been elected by the Kansas City Section for the fiscal year commencing May 1, 1948: *Chairman*, George G. Williamson; *Vice-Chairman*, H. G Abbott; *Secretary-Treasurer*, Sam J. Walker; *Executive Committee Members*, Karl Schmidt, C. J. Sise, J. Frick, L. N. Williams, L. E. Page, E. D. Anderson; *Chairman, Program Committee*, Cecil Poarch; *Chairman, Membership Committee*, Joe Viditto.

LONG BEACH

The June 21st dinner meeting, held at The Sarong Cafe, Long Beach, was well attended. Dick Lee of the Alloy Rods Co., spoke on "Alloys in the Security Program," and Capt. Carmick, of the Long Beach Naval Shipyard, spoke on his experience with welding in the war.

The following officers have been installed for the fiscal year commencing July 1, 1948: *Chairman*, Ray Davenport; *1st Vice-Chairman*, Paul E. Anderson; *2nd Vice-Chairman*, Lee Schexshneider; *Secretary-Treasurer*, Jack Young; *Executive Committee*, Fred Ledger, Art Hilse, Ed Dash, Bob Wortham, A. J. Smoak, Chas. Breese, Paul DePietro, Gail Beckstrand, Bert Keeney, Robt. Fricks, Harold Fitko; *Chairman, Membership Committee*, Art Hilse; *Chairman, Code & Tech. Committee*, Ed Dash; *Chairman, Entertainment Committee*, Bob Wortham; *Chairman, Finance Committee*, A. J. Smoak; *Chairman, Publicity Committee*, Chas. Breese; *Chairman, Advertising Committee*, Paul DePietro; *Chairman, Rec. Sec. Committee*, Fred Ledger.

LOS ANGELES

The following officers have been elected by the Los Angeles Section for the 1948–49 season: *Chairman*, E. O. Williams, Victor Equipment Co.; *Vice-Chairman*, Charles Haynes, C. F. Braun & Co.; *Secretary-Treasurer*, Charles Johnston, Victor Equipment Co.; *Directors*, Fred Pipher, Guy Patterson, M. H. MacKusick; *Program Chairman*, Charlie Haynes.

MAHONING VALLEY

Annual plant visitation to General Fire Proofing Co. Youngstown, Ohio, was held on May 13th. One hundred twenty-five members and guests attended. This company makes steel filing cabinets, desks, etc., using welding in steel fabrication. Also aluminum office and transportation vehicle furniture. This plant visitation was most complete and unusually interesting. A stag dinner meeting was held on June 10th at the Dinner Bell, Youngstown. Sports shorts were shown as incidental entertainment for the meeting.

NEW JERSEY

The following officers have been elected by the New Jersey Section for the fiscal year beginning September 1st: *Chairman*, W. B. Bunn; *1st Vice-Chairman*, J. George Blind; *Secretary-Treasurer*, P. M. Mattern; *Executive Committee*, Walter Begerow, H. H. Comstock, R. McPeek, A. Grodner, E. T. English, E. W. Brass, O. T. Barnett, A. W. Steinberger, R. M. Wilson, Jr., R. Chelborg; *Chairman, Membership Committee*, Ray McPeek; *Chairman, Advisory Committee*, G. W. Nigh; *Chairman, Program Committee*, Walter Begerow; *Chairman, Publicity Committee*, A. Steinberger; *Chairman, Educational Committee*, J. George Blind; *Chairman, Advertising Committee*, O. T. Barnett; *Representative, Tech. Societies Council*, F. C. Fyke.

NEW YORK

An Executive Committee meeting of the New York Section was held on July 14th, at which time the Program Committee announced that T. B. Jefferson, Editor of *The Welding Engineer*, had accepted an invitation to speak at a meeting to be held on September 15th.

NORTHWEST

The following officers and members of the Executive Committee have been appointed for the 1948–49 season: *Chairman*, Robt. J. Stoddard, American Hoist & Derrick Co.; *Vice-Chairman*, H. R. Toll Co.; *Secretary-Treasurer*, Lillian K. Polzin, Minneapolis Chamber of Commerce; *Executive Committee*, C. R. Behringer, C. E. Ekberg, Marshall Ford, E. E. Hall, Jack Hunter, T. M. LeVasseur, W. F. Logemann, V. L. Sage, R. H. Schleuder, F. W. Scott, E. C. Schroeder and Ray T. Schwabe.

NORTHWESTERN PENNSYLVANIA

The following officers have been appointed by the Northwestern Pennsylvania Section for the year 1948–49: *Chairman*, S. V. Williams, Titusville Forge Div., Struthers Wells Corp.; *Vice-Chairman*, Ed. J. Brown, Union Iron Works; *Secretary-Treasurer*, W. R. Boyd, Boyd Welding Co.; *Member Executive Committee*, Fred Perry, Works Lab., General Electric Co.

SOUTH TEXAS

The June meeting was held on the 25th at Post 52, American Legion Hall, Houston. The business meeting was preceded by a one-hour floor show that proved to be very entertaining to a majority of those present. The retiring chairman was presented with a past-chairman pin.

TRI-STATE

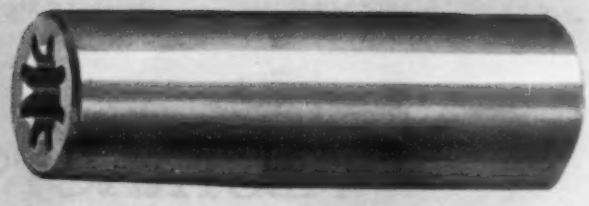
The June meeting of the Tri-State Section was held on the 23rd at the Vendome Hotel, Evansville, Ind. Al Wiltjer spoke on the subject "Pressure Welding."

Another NEW IDEA from
RESISTANCE
WELDING ELECTRODE
HEADQUARTERS...

Eight Flutes increase cooling area 70%.

I.D. is same as O.D. of standard water cooling tubes.

CROSS SECTION



Mallory Fluted Electrodes†

A Mallory Improvement adding 70% more water cooling area

EIGHT FLUTES in the side of the water hole increase the effective cooling area 70%. The "fin-like" effect assures the rapid transfer of heat from the electrode to the cooling water. A cooler electrode means less mushrooming and longer life. Also, higher rates of production can be obtained because of less down time for dressing, less time lost because of overheated electrodes. Shop tests have shown life increases over conventional water hole electrodes of as much as 30%.

Fluted Electrodes prevent the formation of hot spots developing on the sides of electrodes due to misalignment of inlet water cooling tubes. The I.D. of the flutes is just large enough to accommodate standard water cooling tubes. This makes for positive centering of the water inlet tube and guarantees an equal distribution around the water hole of the heat-removing cooling water as it leaves the electrode.

Available now in #2 *Morse taper* truncated cone tips up to 2½" *long*. Other tapers and longer lengths will be available soon. Your inquiries on special tips with MALLORY fluted water cooling holes are invited.

These MALLORY Fluted Electrodes cost you *no more* than the standard drilled water hole electrodes. Put them into your production now and enjoy the savings from another MALLORY development towards better Resistance Welding Electrodes.

In the United Kingdom, made and sold by MALLORY METALLURGICAL PRODUCTS, LTD. (An Associate Company of Johnson, Matthey & Co., Limited, Hatton Garden, London, E.C.1.)

P.R. MALLORY & CO Inc

MALLORY RESISTANCE WELDING MATERIALS

ELECTRODES—HOLDERS—SPECIAL DIES AND FIXTURES—
ELKONITE* METALS—ALLOY ROD AND BAR STOCK—
FORGINGS—CASTINGS—ACCESSORIES *REG. U. S. PAT. OFF.

P. R. MALLORY & CO., Inc., INDIANAPOLIS 6, INDIANA

THE PIONEERS OF ELKONITE*, ELKALOY A*, MALLORY 3*, MALLORY 53B and MALLORY 100 METALS.

† *Patent Applied For*

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Two films, "Pressure Welding on Big Inch" and "Helium Welding," were shown.

WASHINGTON

The Washington Section has attempted an early start this season in order to arrange an especially interesting program for the members. The season's activities will include at least one field trip and one demonstration.

The Executive Committee, at a recent meeting, expressed regret at the departure of A. W. Lubbers from the Section; his business taking him from the Washington area. Mr. Lubbers has been a faithful servant to the Section both in attendance as a member of the Executive Committee and as a contact man in obtaining motion pictures, meeting space and other facilities essential to the successful operation of the Section.

YORK-CENTRAL PENNSYLVANIA

The following officers have been elected by the York-Central Pennsylvania Section for the fiscal year commencing June 1st: *Chairman*, R. K. Lee; *1st Vice-Chairman*, C. Keyser; *Secretary*, G. A. Ostrom; *Treasurer*, C. W. Allen; *Chairman, Membership Committee*, C. E. Lewis Kerchner; *Chairman, Program Committee*, Alex Heilman; *Chairman, Publicity Committee*, Ed Pfeiffer.

ABSTRACTS OF CURRENT WELDING PATENTS

Prepared by V. L. Oldham

Printed copies of patents may be obtained for 25c from the Commissioner of Patents, Washington 10, D. C

2,444,262—APPARATUS FOR FORMING WELDING TAPE—Floyd C. Knight, East Cleveland, and John R. Pierce, Cleveland, Ohio, assignors, by mesne assignments, to Arcrods Corp., a corporation of Delaware.

This patent covers a device for forming a welding tape wherein the device includes a dipping receptacle that has driven fabric-guiding means provided therein. Means for agitating the contents of the receptacle also are provided.

2,444,565—WELDING ELECTRODE HOLDER—Herman J. Hecht, South Bend, Ind. (6 Claims. Cl. 219—8)

Hecht's electrode holder has a conductor shaft slidably mounted within a tubular handle member. Means are provided for controlling the axial position of the conductor shaft to aid in electrode support thereby.

2,444,654—NICKEL ELECTRODE FOR WELDING CAST IRON—Theodore Ephraim Kihlgren, Scotch Plains, N. J., assignor to The International Nickel Co., Inc., New York, N. Y., a corporation of Delaware. (5 Claims. Cl. 219—8)

This special arc-welding electrode includes a core wire containing between 98.5 and 99.5% nickel. A flux including large parts of carbon and iron powder and a small part of titanium and about 45 to 85 parts slag-forming materials is provided for the core wire.

2,444,767—GAS-ARC WELDING APPARATUS—Richard W. Cobean, Schenectady, N. Y., assignor to General Electric Co., a corporation of New York. (2 Claims. Cl. 219—14)

This patent relates to a handle for supporting and supplying gas and electric current to the electrode-holding nozzle of a gas-electric torch. The handle has a resilient gas-carrying tube provided therein. A roller member bears on the tube, and is moved longitudinally of the handle for compressing the tube and controlling gas flow therethrough.

2,444,778—APPARATUS FOR WELDING TUBING—Walter Kopec, Cleveland, Ohio, assignor to Republic Steel Corp., Cleveland, Ohio, a corporation of New Jersey. (5 Claims. Cl. 219—6)

A mandrel for use with atomic-hydrogen tube welding apparatus, and the mandrel has a special top surface portion provided thereon with a gas passage opening at such special top surface, is covered in the patent.

2,444,798—ELECTRODE ADAPTER—Wayne E. Wilson, Schenectady, N. Y., assignor to General Electric Co., a corporation of New York. (5 Claims. Cl. 219—8)

Wilson's adapter is used with carbon electrodes in arc-welding operations wherein the electrode holders have a jaw spread less than that required. The adapter includes cooperating hinged members adapted to be secured to and longitudinally protrude from the jaws of the electrode holder.

2,444,834—HIGH-SPEED ARC WELDING—George G. Landis, South Euclid, and Norman J. Hoenie, Cleveland Heights, Ohio, assignors to The Lincoln Electric Co., Cleveland, Ohio, a corporation of Ohio. (7 Claims. Cl. 219—10)

This patented welding process includes the feature of imposing on the terminal portion of the electrode an arc-welding current of such high density that it produces more heat by the resistance heating of the terminal electrode portion than is absorbed by such portion from the arc at the electrode end

2,444,850-1—HEATING AND BRAZING TORCH—Malone L. Rogers, Portsmouth, Va. (3 Claims. Cl. 158—27.4); (2 Claims. Cl. 158—27.4)

These patents cover a special type of a torch wherein two concentric, radially separated, annular gas supply ports are provided in the torch. Another feature of one construction is that the inner gas supply port may protrude axially beyond the outer port.

2,444,994—WELDING FLUX—Kenneth H. Koopman, Kenmore, N. Y., assignor to Haynes Stellite Co., a corporation of Indiana. (3 Claims. Cl. 148—26)

This welding flux includes small amounts of sodium chloride and calcium fluoride. Relatively larger amounts of sodium carbonate and sodium sesquicarbonate also are in the flux, with the flux also including between 45 and 60% of borax glass.

2,445,747—INDENTATION-FREE WELDING—Michael Watter, Philadelphia, Pa., assignor to The Budd Co., Philadelphia, Pa., a corporation of Pennsylvania. (8 Claims. Cl. 219—4)

This patent relates to resistance welders and one electrode tip is of lesser diameter than the other electrode tip. A tube of electrically nonconducting material surrounds the smaller electrode tip. The bearing face of the tip and the tube of the one electrode lie in a common plane which lies at right angles to the axis of the electrode carrying same.

Employment Service Bulletin

POSITION VACANT

V-228. Research Engineer. Opening at Eastern University for man capable of taking charge of a research program concerned with the fracture and ductility properties of steel, Opportunity to work for advanced metallurgical or civil engineering degree. Metallurgical training desirable. Salary up to $3600 depending on experience. Applicants for this position should submit complete scholastic and experience record, together with a recent photograph.

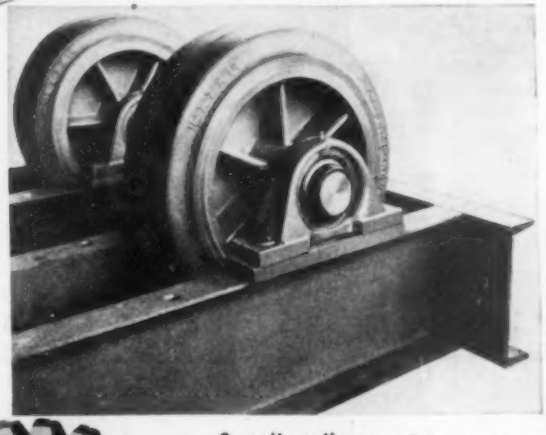
NOW—a new improved line of Ransome TURNING ROLLS

for bigger profits, faster production, better welds

New lowered drive mechanism permits unobstructed loading from either end of rolls.

Anti-friction bearings used where necessary to insure easy rotation under heavy loads.

Bronze-and-steel worm wheel construction for added strength.



Out of Ransome's vast war experience in tank welding has come a new, more efficient line of Ransome Power and Idler Turning Rolls. Three completely new models, A, B and C, offer such profit-building features as: anti-friction bearings, to insure easy rotation under heavy loads . . . a new lowered drive mechanism to permit unobstructed loading from either end of rolls . . . combination steel-and-bronze worm wheel for greater resistance to stresses from heavy loads (a new and exclusive Ransome feature) . . . rubber tired rollers to absorb shock and cushion seams in automatic welding.

Capacity ratings, which are conservative, are as follows: Model A, 4½ tons; Model B, 20 tons; Model, C45 tons.* Information on larger capacity models on request.

For complete details on this new line of Ransome Turning Rolls for Manual or Automatic Welding, mail coupon for special bulletin.

*In each case, with rubber tired rollers.

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DUNELLEN, NEW JERSEY

Subsidiary of

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Industrial Division
Ransome Machinery Company
Dunellen, New Jersey

Please send me, without obligation, the bulletin on the new improved line of Ransome Turning Rolls.

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List of New Members

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Beck, Virgil S. (B)
Bienz, Donald C. (B)
Birt, Glen D. (B)
Boggs, Garold (B)
Carter, Carl (B)
Clark, Max (B)
Collins, James L. (C)
Couts, Joe (B)
Craig, Howard R. (B)
Cushing, Wm. Marvin (B)
Diebold, R. A. (B)
Doty, Glen C. (B)
Force, Earl (B)
Grabach, E. L. (B)
Gray, Eugene (B)
Johnson, Harry M. (B)
Kinley, Wayne C. (B)
Lang, James F. (C)
Laws, George H. (B)
Leaming, George A. (B)
Lombardo, John J., Sr. (B)
McCoy, R. C. (B)
McNutt, Russell F. (B)
Nofzinger, Elmer (B)
Nofzinger, Ray (B)
Russell, George H. (B)
Schmidt, Fred (B)
Smith, Harold C. (B)
Snyder, Lorin A. (B)
Springer, Gerald E. (B)
Wilson, John Woodrow (B)
Wilt, Fred C. (B)
Zimmerman, K. H. (B)

BIRMINGHAM

Walsh, Robert J. (B)

BOSTON

Cassidy, Perry R. (B)

CHATTANOOGA

Hargis, Raymond (B)

CHICAGO

Colin, Edward C., Jr. (C)
Pinsky, Jerome D. (C)

CLEVELAND

Ratzburg, Paul D. (B)

COLUMBUS

Kelker, David R. (C)

DETROIT

Binkley, Theodore M. (C)
Cinka, Joseph (B)
Merker, Henry M. (B)
Stephens, W. R. (B)
Whitsel, Roy (C)

INDIANA

Orelup, Mark J. (D)

INLAND EMPIRE

Haskins, Roy (B)

KANSAS CITY

Libby, Hugh L. (B)

LONG BEACH

Koenig, Frederick P. (C)

LOUISVILLE

McLaughlin, Carl B. (C)

MAHONING VALLEY

Jennings, J. Carroll (C)
Jones, Frank Q., Jr. (C)

MARYLAND

Clautice, William E. (C)

NEW ORLEANS

Drury, Lloyd Leonard (D)
Duffy, Mike (B)
Haddad, Stephen (B)
Hebert, Kenneth (B)
Krajovic, Paul (C)
Martin, J. H. (B)
Mlinar, E. J. (B)
Pitman, A. T. (B)

NEW YORK

Herzog, Wm. G. (C)

NORTHERN NEW YORK

Kearney, Charles F. (C)
Klein, Joseph H., Jr. (C)

PHILADELPHIA

Joseph, Edwin R. (B)

PITTSBURGH

Edlund, D. L. (B)
MacDermod, Elliott (C)

PUGET SOUND

Freeman, Billy S. (B)

SAN FRANCISCO

Keading, Lewis C. (B)

SOUTH TEXAS

Wells, James T., Jr. (B)

TOLEDO

Cammarata, James J. (C)

TRI-STATE

Barnard, R. K. (B)
Dickerson, Morton (B)
Embry, Wesley (B)
Pedigo, Haskell (B)

WASHINGTON

Rieley, Julius H. (C)

WESTERN MICHIGAN

Howell, Donald L. (B)

WICHITA

Taylor, Max (C)

YORK-CENTRAL PA.

Zercher, Kenneth C. (B)

NOT IN SECTIONS

Ambuehl, Paul V. (C)
Bullard, Ben (C)
Cartlidge, Willard A. (C)
Chyle, W. W. (B)
Cohron, O. M. (B)
Coyle, J. Edward (C)
Dodd, L. E. (C)
Edwards, Ira B. (B)
Fathers, R. B. (B)
Ferris, Thomas Anthony (D)
Gidel, Elmer G. (C)
Hamm, Robert Roy, Jr. (C)
Henne, Wm. L., Jr. (B)
Jimenez, Louis A. (C)
Marina, Joe F. (C)
Stokes, Claude (C)
Thomas, Hamp (B)
Torroja, Eduardo (B)

ANNUAL MEETING
AMERICAN WELDING SOCIETY

HEADQUARTERS BELLEVUE STRATFORD HOTEL, PHILA., PA.
OCTOBER 24 to 29, 1948

The Annual Meeting of the American Welding Society will be held in conjunction with the National Metal Congress and Exposition. Some 67 papers in 21 sessions will be given covering every phase of welding such as Ship Design, Railroad, Storage Tanks, Pressure Vessels and Piping, Ship Structure Research, High Alloys-Non Ferrous, Brazing and Metallizing, Cutting, Weldability, Arcs and Electrodes, Resistance Welding, Inert-Gas-Shielded Arc, Structural, Maintenance, Automatic Welding, Hard Facing and Flame Hardening.

Everyone can participate in this Annual Meeting. Some of the papers are published in this issue. Additional papers will be published in the October number. If you have discussion of any of these papers please send in such discussion at once.

Hotel reservations should be made promptly. If you have not made hotel reservations, get in touch with Charles L. Todd, Manager, Housing Bureau, Architects Bldg., 17th and Sansome Streets, Philadelphia 3, Pa.

An unusual feature of this Annual Meeting will be a series of lectures on "The Metallurgy of Arc Welds in Steel." Presented by Dr. R. D. Stout, Department of Metallurgy, Lehigh University, the lectures will be given on Monday, Tuesday and Wednesday, October 25th, 26th and 27th, from 4:30 to 6:00 p.m. at the Commercial Museum and Convention Halls.